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ENERGY EVALUATION OF WATER MANAGEMENT ALTERNATIVES IN THE UPPER ST. JOHNS RIVER BASIN OF FLORIDA

Suzanne Bayley, et al

Environmental Protection Agency
Gainesville, Florida

May 1973

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ENERGY EVALUATION OF WATER MANAGEMENT ALTERNATIVES IN THE UPPER ST. JOHNS RIVER BASIN OF FLORIDA

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May, 1973

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Report of EPA Water Program, Region IV Office,
Atlanta, Georgia, made in collaboration with
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ABSTRACT

This is an energy evaluation of water management alternatives in Brevard County, Florida, a section of the upper St. Johns River basin. This area was selected as a pilot test of the energy evaluation procedure for decision making in the upper St. Johns River. Value was determined with the principle that the work done by ecological systems and the work done by the economic systems of man both contribute to the economic viability, long range stability, and quality of a region. Economic viability is based on the principle that systems survive and prevail that maximize their useful work from all sources. Energy value calculations were made for the present condition, the primitive condition, and three alternatives for water management in the upper St. Johns River basin: a pattern of private channelization of lands for agriculture and housing; a reservoir plan that sends more water to agriculture and urban use in other districts; and a plan that retains the floodplain for water conservation areas.

First, network models were drawn to inventory the main pathways of water interaction, the main energy sources, and the main categories of concern. Then annual work values were estimated for each of the main pathways contributing to value. Water availability, fluctuating water levels, and nutrients were main factors in the generation of value, and details on these systems are given in Part II. Proposed changes in water management and land use shift the distribution of energy values and thus change the totals of energy generated by the regional scale interactions of lands, waters, cities, and outside sources of money and energy.

Whereas decisions about the whole basin of the upper St. Johns River covering six counties can not be made from an energy evaluation of just one county, the pilot area calculations suggest energy amplifier factors for water for alternatives of marsh use, lightly managed pasture and intensive agriculture, urban development based on water-using industries, urban development based on light industry, and urban development based on tourism and retirement. The greatest return per gallon of water was highest for urban development where a government payroll was insured, and least for intensive agriculture, when water was viewed as an isolated factor. Where fossil fuels are becoming more expensive the greatest energy return per gallon of available water was calculated to be highest for a diversified land use of marsh in the wetland areas, urban communities on the higher coastal land and agriculture on the intermediate elevations.

The calculations on Brevard County under five alternatives involve several kinds of sources of outside energy and outside economic incomes. Trends in energy value were considered for the possibilities of continued pressure for growth and for several possibilities where energies and money for further development.

The energy cost-benefit approach used in this report avoids several fallacies common to other evaluations of environmental change. The large work contributions of nature which are not affected by money and whose services it is frequently difficult to itemize are not ignored. This approach by considering the total system avoids the deceptively high amplifier effects of processes examined in isolation. The high value frequently placed on water for urban use or for irrigation assumes that other processes elsewhere in the system will remain constant and that the total system will not be changed by the changes in one isolated factor. This is not the case and changes in one factor can have profound ramifications throughout the system which are not considered since the money flows remain unaffected until long after the development and high density may affect the viability of the area.

Using this approach the calculations showed the plan for retention of marshes produced the highest total annual energy value, suggesting this plan as the one most favorable to economic vitality. The lowest values were found with further private channelization and development of the kind of agricultural production now practiced. The U. S. Corps of Engineers plan produced lower combined values than the plan that retains more marsh.

ACKNOWLEDGMENTS

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INTRODUCTION

Need for Evaluation of Water Management Alternatives

The economic growth in Florida over the last 20 years has created water and land use problems in the upper St. Johns River basin (Fig. 1) which are repeated in many parts of the state. The expansion of agriculture into areas previously covered with standing water diverted water to the sea, reduced the flood plain and marshes and increased the need for irrigation water. Water flow has diminished in the rivers and marshes particularly during the dry season when water is especially needed by cities and by agriculture. In the wet season the reduced flood plain and increased runoff from channelization have caused the water to flow faster downstream and flood other areas. The channelization and agricultural runoff have caused eutrophication, spread of water hyacinths, and organic sedimentation in some of the lakes. Demands have developed for agricultural water potentially in conflict with the demand for water by the urban population and the demand for green panoramas by tourists, residents, outdoorsmen, and retirees.

Anticipating further growth and new demands for water, several plans were offered for water use affecting the river, the marshes, and new farms and cities. Questions were raised as to which pattern for water management was most valuable to the general overall public interest. Uncertainties about energy reserves and U. S. balance of payments raised doubts about continued pressures for growth.

Brevard County has had rapid urban development due to federal payrolls and tourists in the eastern coastal portion of the county and extensive agricultural development with drainage to the west.

Conservation groups question the desirability of draining the marshes. In most of Brevard County the drinking water supply cannot be obtained from aquifers because of their salinity and must be obtained from the fresh water lakes, which have been greatly reduced in size, or from another county. In an attempt to provide for both agricultural and urban water requirements, the Central and Southern Flood Control District (FCD) and the U. S. Army Corps of Engineers have made proposals to manage the water in a series of upland impoundments, floodplain reservoirs and channels (Fig. 2).

A draft Environmental Impact Statement (EIS) as required by the National Environmental Policy Act of 1969 (Public Law 91-190) was distributed by the Corps of Engineers in 1971 for the entire Central and Southern Florida Flood Control Project, only a part of which involved the upper St. Johns River area. Review comments from various agencies indicated a need for segmenting the project so environmental impact statements could be prepared for each of four separate elements. It was agreed that because of expected significant impacts on the environment, special studies would be undertaken by EPA in the upper St. Johns to assist in the evaluation and review of that specific element. EPA, therefore, contracted with the authors to undertake this study.

What are the effects of these proposals on the whole region? Will agricultural use of land and water increase, and will this increase be to the detriment of the natural ecosystems? Since private diking is taking over the marsh very rapidly, will the reservoirs increase or decrease many areas of the floodplain by covering them with water?

What is the annual value of the present land in agriculture, urban use, and in natural marsh? How will this be changed by the proposed reservoirs? What effect will the reservoirs have on the urban demand for water and on water quality? Will the value of the whole region, urban, agriculture, and natural, be increased or decreased by the project? What is the best combination of uses of the waters and lands?

To answer some of these questions and show the impact of alternative plans, some new methods were used to compare alternatives. Land use maps and calculations of water budgets were used to estimate annual energy values of each alternative plan that was proposed. We call this procedure an energy cost-benefit approach.

Energy Value and the Maximum Power Principle

At the basis of this evaluation is the principle that systems survive that maximize their energy flow (work) for useful purposes. Systems of man and nature are subject to natural selection and according to Lotka (1922) the criterion for natural selection is that systems maximize power for useful purposes. In a book discussion this principle was suggested as a basis for evaluation of the components of value from man and nature (Odum, 1971). The principle states that the system that maximizes its useful energy will be the one that survives. This means that if several areas are competing for limited resources and people, the area that can realize and maintain the largest useful work (total useful energy flow) will be the one that will survive. Useful work comes from nature and from man so that the region that can find the best balance of man and nature is going to be the one that survives, both energetically and economically. During times of energy growth, survival depends on maximizing growth, but when growth has reached the resource carrying capacity, maximizing power means making more effective use of all energies. This principle provides guidelines for determining which plans and designs for Broward County may be successful.

We believe that ultimately people regard as good and right that which has been part of a successful working economy of both man and nature and that energy calculations give an advanced indication of people's views.

Following some other efforts to do energy cost-benefit calculations (Odum, 1971, 1972; Odum, Littlejohn, and Huber, 1972) value here is measured as the useful flow of energy (work) whether it be done by man, machines, or by natural ecosystems without man. This work is measured in kilocalories of energy. If change in one flow, such as water, has secondary effects through its participation or control of another flow, this change will be reflected in the total value. The activities of man and machines have traditionally been measured in money, but money measures only the work of man, not that of nature. In this study, models and land use maps were means to identify and evaluate the main energy flows.

Description of the Region

As shown in Fig. 3 the St. Johns River emerges from dense marshes in east central Florida and flows 260 miles north to the sea. The northern two-thirds of the river has high salt content from ground water flows and receives tidal changes in water level although sea water does not move so far up river. The southern third of the river is primarily fresh water, however recent data indicates that the salinity of the region is increasing particularly during the dry season. The land in this region is very flat with the average gradient of the river for the entire distance only 0.15 feet per mile. This flat topography makes the region and the river drain slowly so that extensive marshes and swamps form a broad floodplain on both sides of the river. There are few urban areas located along the river where development has been slow compared to areas along the beaches and estuaries.

The upper St. Johns River district, the area of interest in this study, was a land of meandering river channels, shallow fresh water lakes and extensive marshes. Part of this pattern still exists. Tributaries, flowing through cypress swamps, bring upland runoff down to the marshes and the river. The river emerges from the dense sawgrass and passes through a number of shallow lakes, shown in

Fig. 1. These include Lakes Helen Blazes, Sawgrass, Washington, Winder, Poinsett, and Harney. Blue Cypress Lake far to the south was considered part of the river basin although no discernable channel linked this lake to Lake Helen Blazes. The vegetation in this area is similar to the sawgrass marshes of the Everglades and has a deep peat substratum. Further to the north near Lakes Sawgrass and Washington the marsh vegetation consists of very tall dense reeds and other moist soil communities. In the region near Lake Poinsett north to State Road 50, short marsh vegetation predominates. North of State Road 50 to Lake Harney many brackish water species join other native pasture grasses.

In this century much of the natural floodplain has been channelized and diked so that in many places it has been reduced from 13 miles in width to 1 mile (Fig. 2). In the most southern reaches entire drainage districts have been made with the water diverted east to the Indian River estuary along the coast. The drainage has been for agricultural production of sugar cane, citrus, and cattle. In those areas still in natural marsh vegetation, cattle, roaming over the floodplain, have caused plant species characteristic of grazed land to become dominant. Current land ownership maps for the region (Fig. 4 and 5) show relatively few owners.

The plans proposed by the Central and Southern Flood Control District (FCD) in the upper St. Johns include three upland impoundments stretching along the western bank of the floodplain parallel to the river. These are Fort Drum Retention Area, Blue Cypress Retention Area and Jane Green Reservoir. Principal areas are shown in Fig. 2. The valley reservoirs include Lake Wilmington Reservoir with a long outlet canal, Lake Washington with a short outlet canal, and Lake Poinsett Reservoir. An additional low weir structure is proposed for Puzzle Lake to prevent overdrainage.

This study initially was concerned only with the marsh between State Road 520 and 50. Since then, however, the scope of energy evaluation was enlarged to include all of Brevard County. The energy cost-benefit method requires that a larger area be evaluated than that of the problem. Thus energy evaluation limited to one county can not answer value questions about larger regions and competitions among counties unless they are included in models and calculations. However, we do calculate energy value criteria for priorities in water use based on Brevard County, which are applicable to the region.

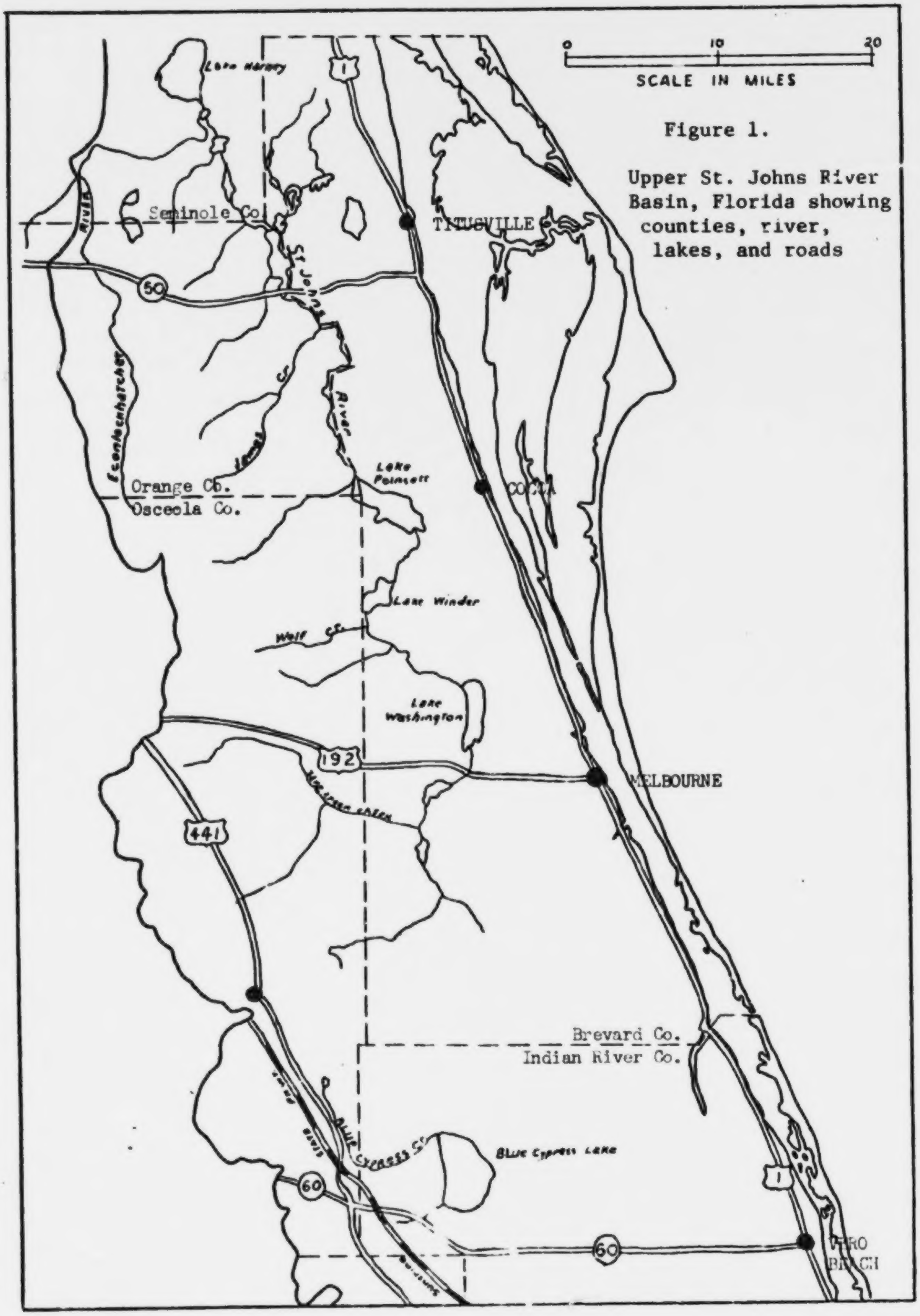

Figure 1.

Upper St. Johns River Basin, Florida showing counties, river, lakes, and roads

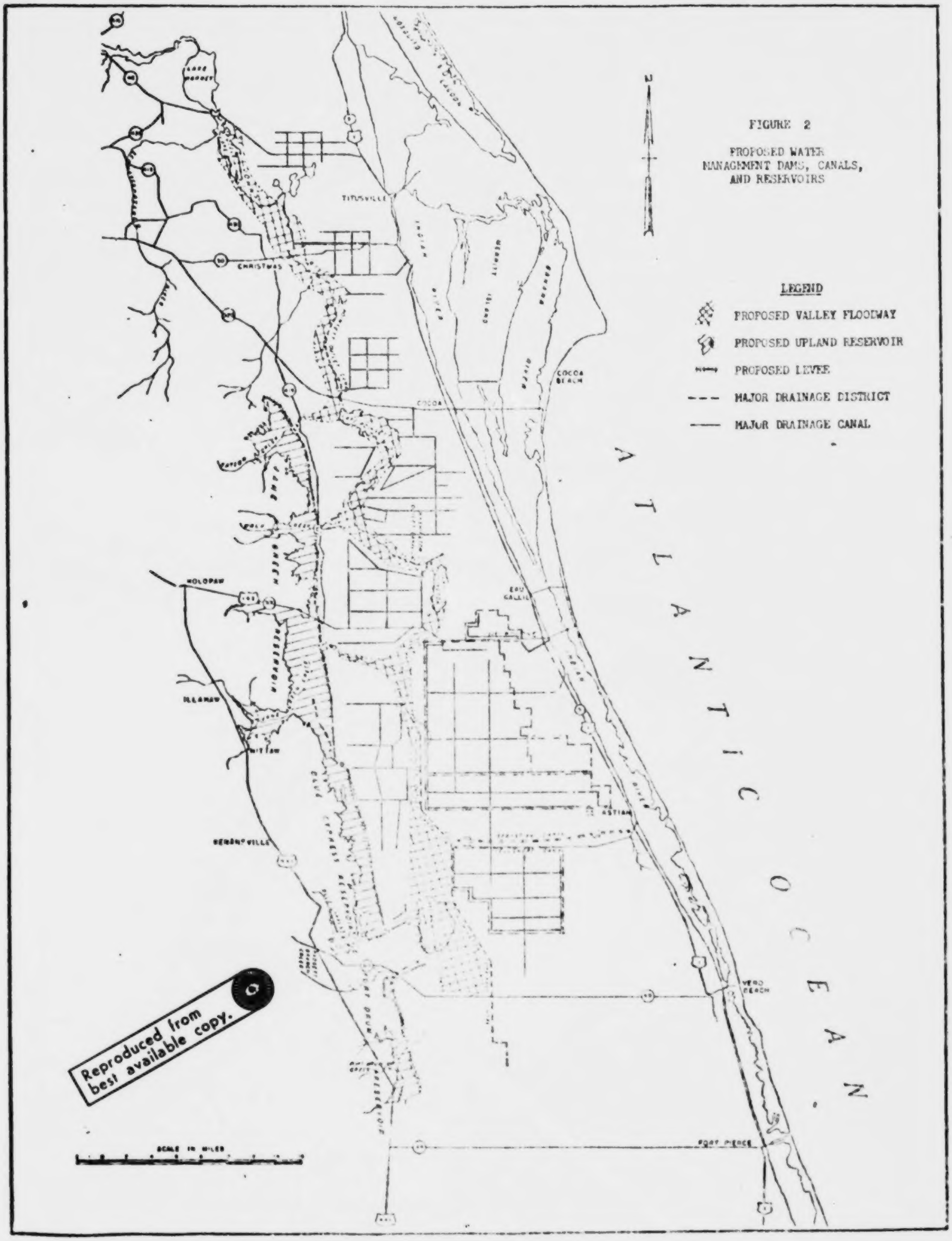

FIGURE 2

PROPOSED WATER MANAGEMENT DAMS, CANALS, AND RESERVOIRS

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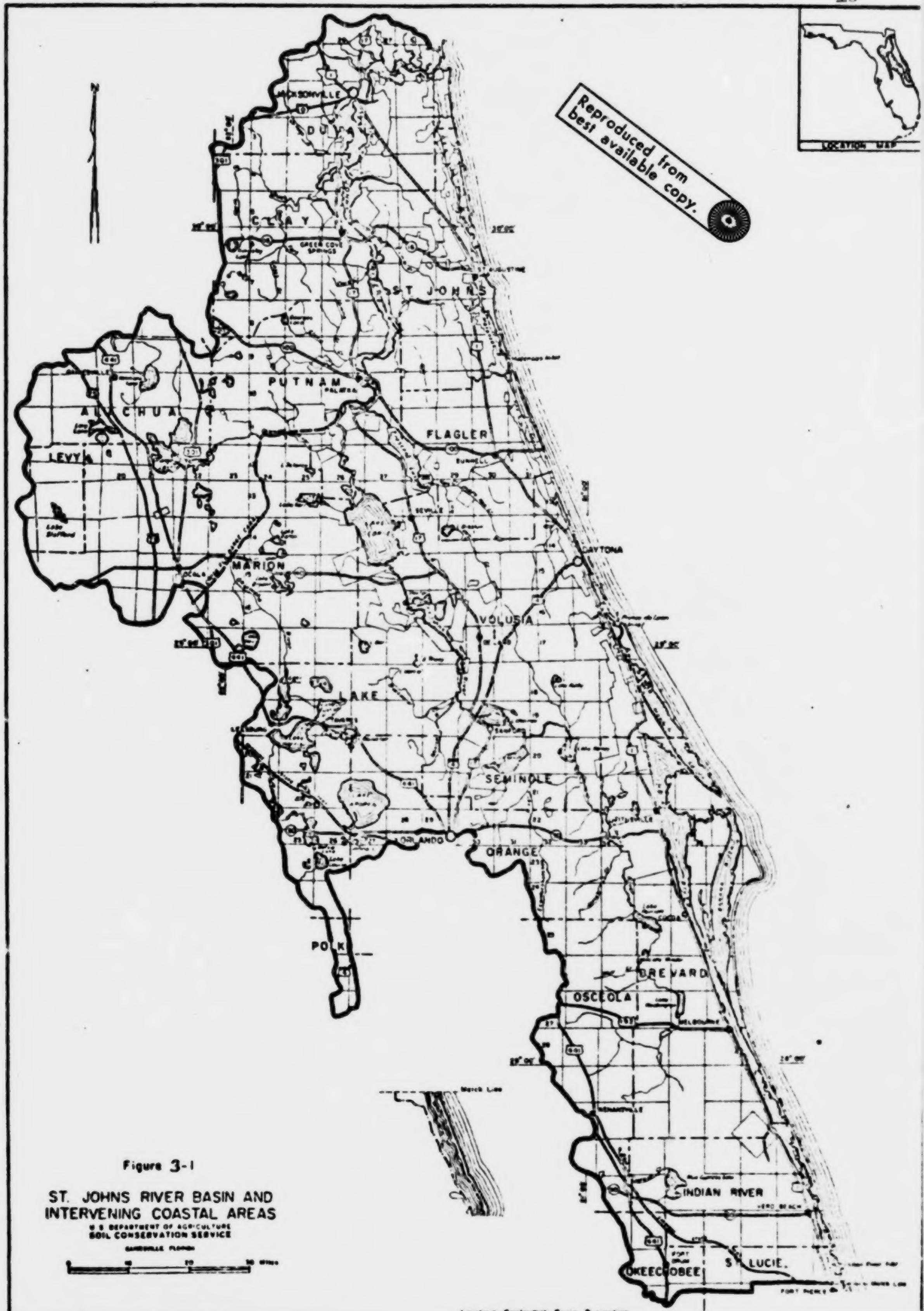

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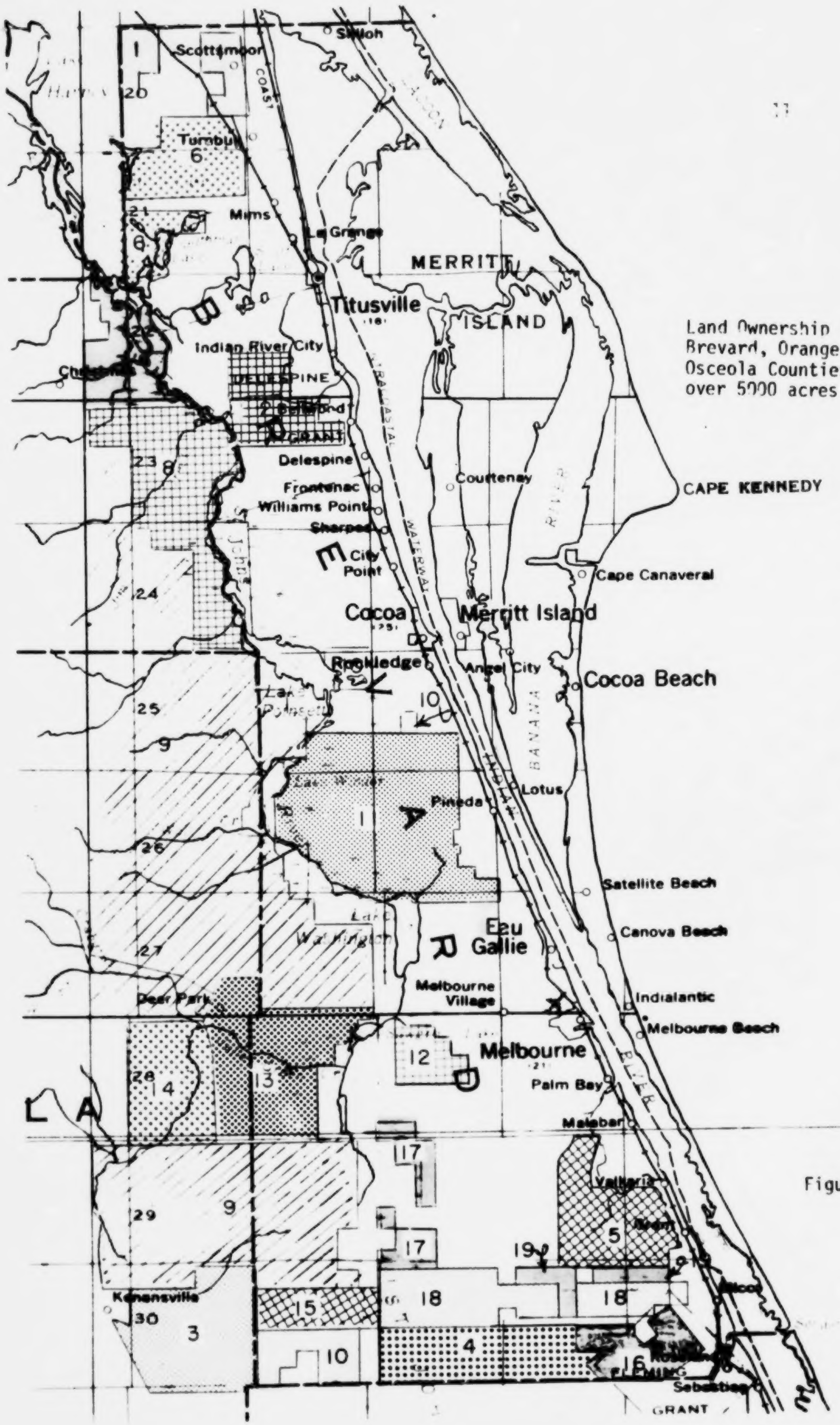
Figure 3-1

ST. JOHNS RIVER BASIN AND
INTERVENING COASTAL AREAS
U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
GAINESVILLE, FLORIDA

From USDA River Basin Investigation, 1969



Land Ownership in
Brevard, Orange, and
Osceola Counties
over 5000 acres

Figure 4

Legend to Figure 4

11a

Brevard, Orange, and Osceola Counties
within the St. Johns River Basin
includes ownership over 5000 acres only

1	Miami Corp.
6	Comm. Bank and Trust
2	Pen Val Realty
10	Gilbert A. Tucker
11	Duda and Sons Corp.
9	Deseret Farms of Fla.
12	Roy Platt
13	Carolyn Kempfer
15	Wye River Farms
14	Flood Control Dist.
4	Gulf Western Indust.
17	Minor Platt
19	Brevard Land Co., Inc.
5	Atlantic Ridge Corp.
16	Hugh Corrigan
18	Real Estate Resources
3	Irlo Bronson
8	Tootoosahatchee Game Pers.
■	Seminole Cattle Co.

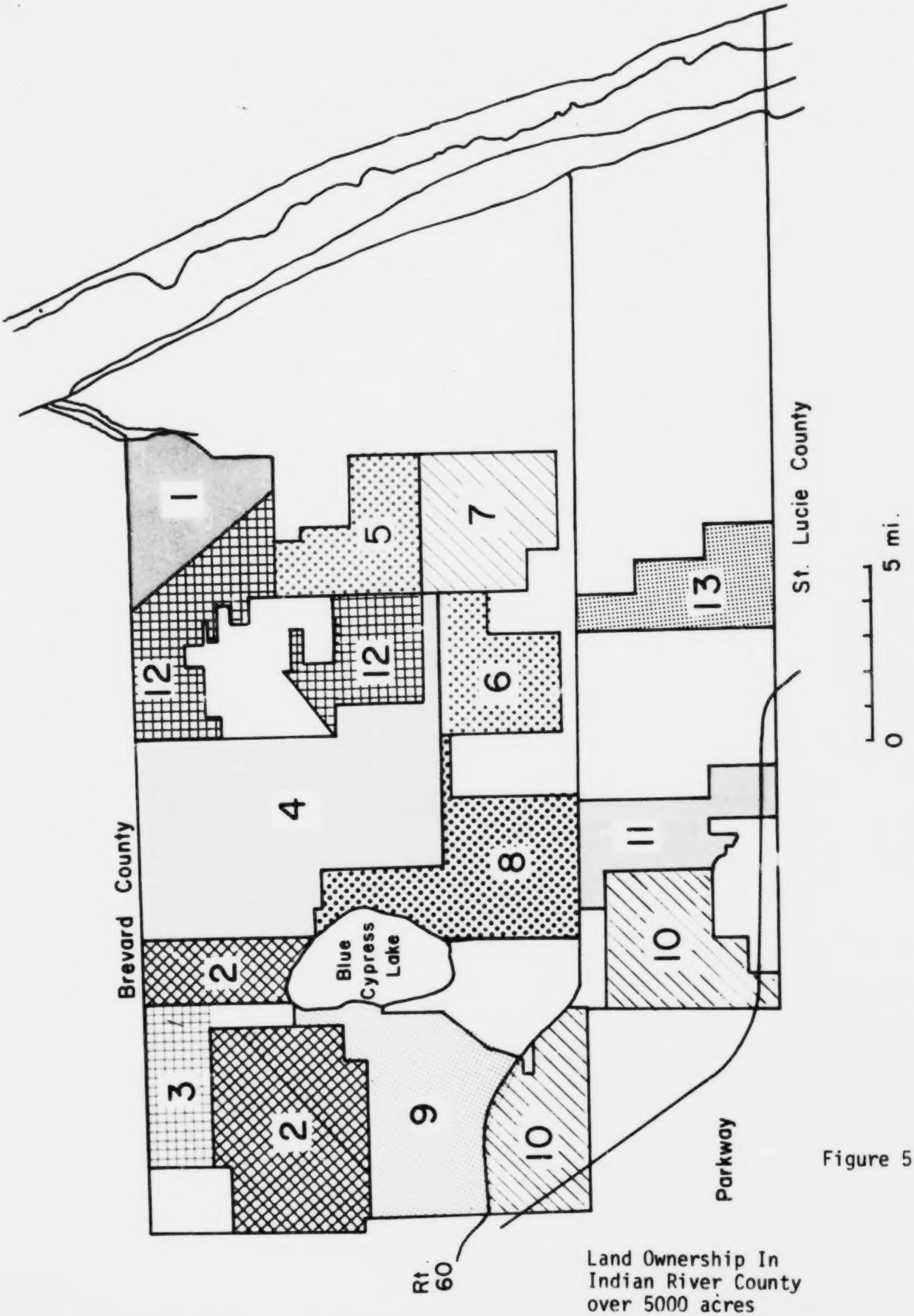


Figure 5

Land Ownership In Indian River County over 5000 acres

Legend to Figure 5

INDIAN RIVER COUNTY

includes ownership over 5000 acres only

■	W W Ranch
2	Fondren Mitchell
3	Blue Cypress Ranch
4	Gulf Western Indust.
5	Fred Bass
6	Anson
7	Pat Carrigan
8	Troy Moody
9	Surrency
10	Maxey
11	C. T. Scott
12	Carson Platt
13	Fred Tuerk

Five Alternatives Used in the Evaluation

In calculating the annual energy values in the region, five different management alternatives were considered: the primitive and present state and three possible development trends for the future.

1. Primitive Condition

The natural land use in Brevard County prior to any development by man is shown in Fig. 6. All of the original vegetation and ecological community structure contributed to the total energy flow. By long selection energy maximizing interactions between the water, soil, and vegetation had developed characteristic land forms that were self controlling and provided quality waters and rich wildlife resources.

2. Present Land Use Alternatives

The main land uses in existence in Brevard County in 1970 are shown in Fig. 7. These include urban systems and agricultural uses (both citrus and cattle), as well as the major natural ecosystems. The major natural ecosystems are the river, lakes, marsh, pine-palmetto communities and hardwood (cypress) communities. Field measurements were made of the productivity of marsh, pasture and river ecosystems.

Under present uses irrigation demands are met by the private owners. Drainage districts divert much water from the newly drained agricultural land to estuaries rather than to the river and remaining floodplain. Eutrophication and organic sedimentation are prevalent in the sections of the river dominated by agricultural runoff. Recent studies indicate salinities are higher now during periods of low water. The land use map developed for the current (1970) derives from detailed aerial photographs and a detailed urban land use study (Existing Land Use Survey and Analysis, 1970).

3. Continued Private Development in the Floodplain

Fig. 8 shows projected land use assuming continuation of recent channelization and drainage for agricultural purposes by private interests. Current ownership maps (Fig. 4) were used to project urban and agricultural developments and the pattern of land use.

Under this alternative the private owners provide irrigation water and drain excess water. The urban water will be supplied from Lake Washington which receives water that remains after agricultural waters have been diverted. Present trends toward further eutrophication, sedimentation, and salinity increases may be expected to continue.

4. New Construction of Reservoirs and Channels Proposed by the U. S. Army Corps of Engineers and the Central and Southern Florida Flood Control District (FCD)

The proposed construction of 3 valley reservoirs (Lake Poinsett Reservoir, Lake Washington Reservoir, and Lake Wilmington Reservoir) and a series of parallel reservoirs and detention areas (Jane Green Reservoir, Blue Cypress Detention Area, and Fort Drum Detention Area) was presented in Fig. 2. Possible changes in the land uses resulting from the reservoir system are presented in Fig. 9.

Rain and runoff from the western slope of the valley will be managed in the parallel upland impoundments. Water from impoundments will be diverted south to provide irrigation water for agriculture in much of Brevard and Indian River Counties. Urban drinking water needs will be supplied from one of the valley reservoirs, Lake Washington. Flood conditions in the valley are to be controlled by the reservoirs.

Under this alternative much of the current marsh land will become a lake. Agricultural use of the remaining land west of I-95 will increase. Further urban development will depend on the availability of Federal payrolls and energy availability and economic conditions in the rest of the U. S. affecting economic investment, inflow of tourists, retirees, and new industrial enterprises.

Data from similar stabilized lakes (Brezonik, et al., 1969; Wagner and Holcomb, 1972) in Florida indicate that eutrophication and sedimentation may limit effectiveness and life of the valley reservoirs. With diversion of water south, and subsequent loss due to transmission and diversion to the sea water may be short for urban supply in dry periods.

5. Floodplain Conservation and Recycle Plan

Fig. 10 presents a land use pattern resulting from an alternative water management plan in which the floodplain is maintained as a series of naturally fluctuating lakes and marshes. Diversions of all runoff and rain from the entire upper St. Johns River basin to the ocean are prevented and used irrigation waters are returned through marshes to the St. Johns River. No public or private canals are permitted within the floodplain. Agricultural development is restricted to higher elevations and no agriculture permitted in the floodplain. In the floodplain only the natural seasonally fluctuating water levels are allowed. Agricultural users in the basin provide irrigation water from ponds or other reservoir storage on their own property. More natural area is available to absorb major floods. Since no diversion of water is permitted out the basin, shallow aquifers will be maintained at higher levels and can be used to provide additional irrigation water. Salt water intrusion is diminished. Drainage canals for improved pastures, citrus and truck crops in the higher elevations are terminated in the upland marsh and the water permitted to drain slowly through the marsh and eventually to the floodplain. This type of plan for recycling of wastes on marsh and swamp lands is being

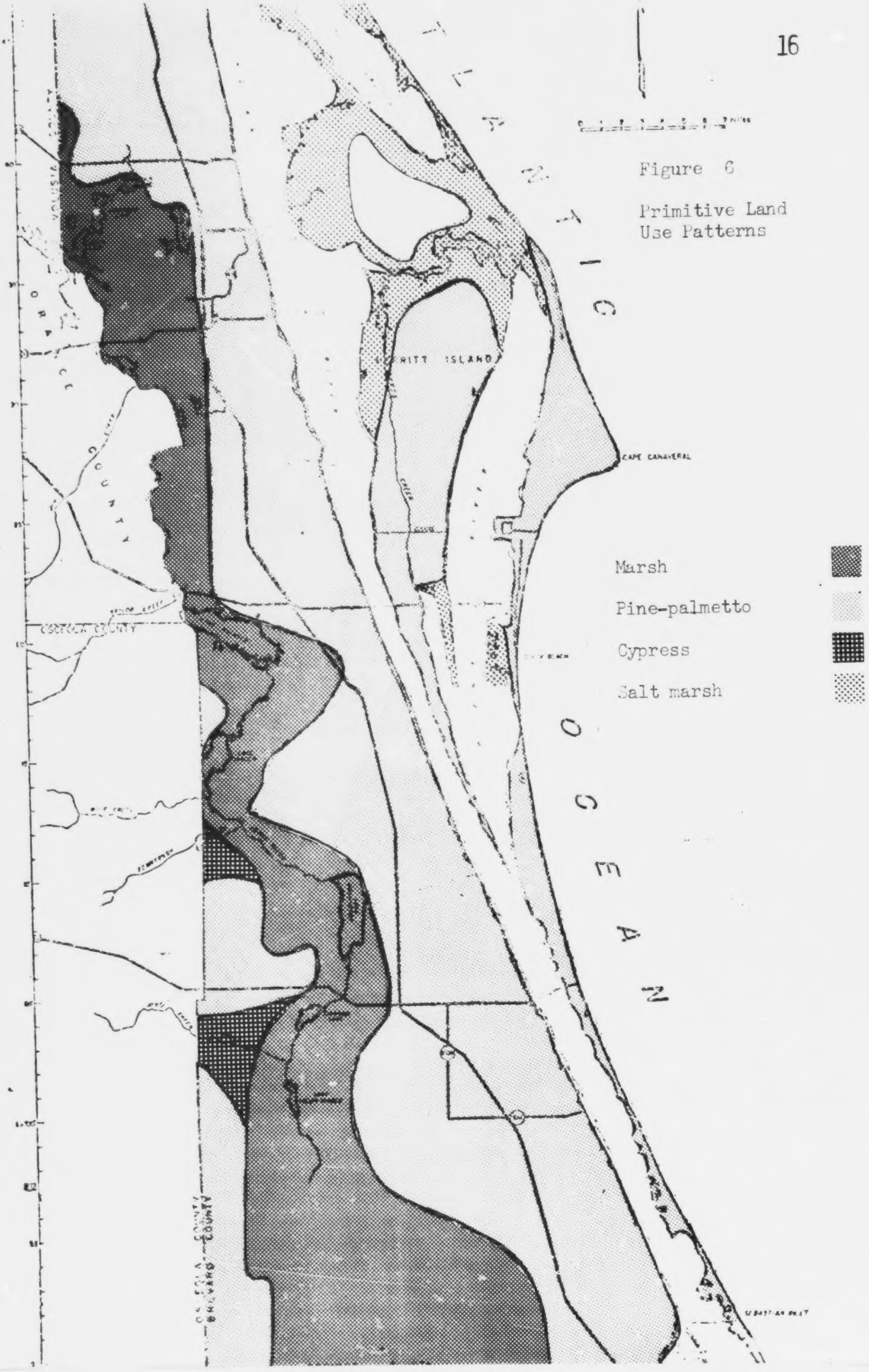


Figure 6

Primitive Land Use Patterns

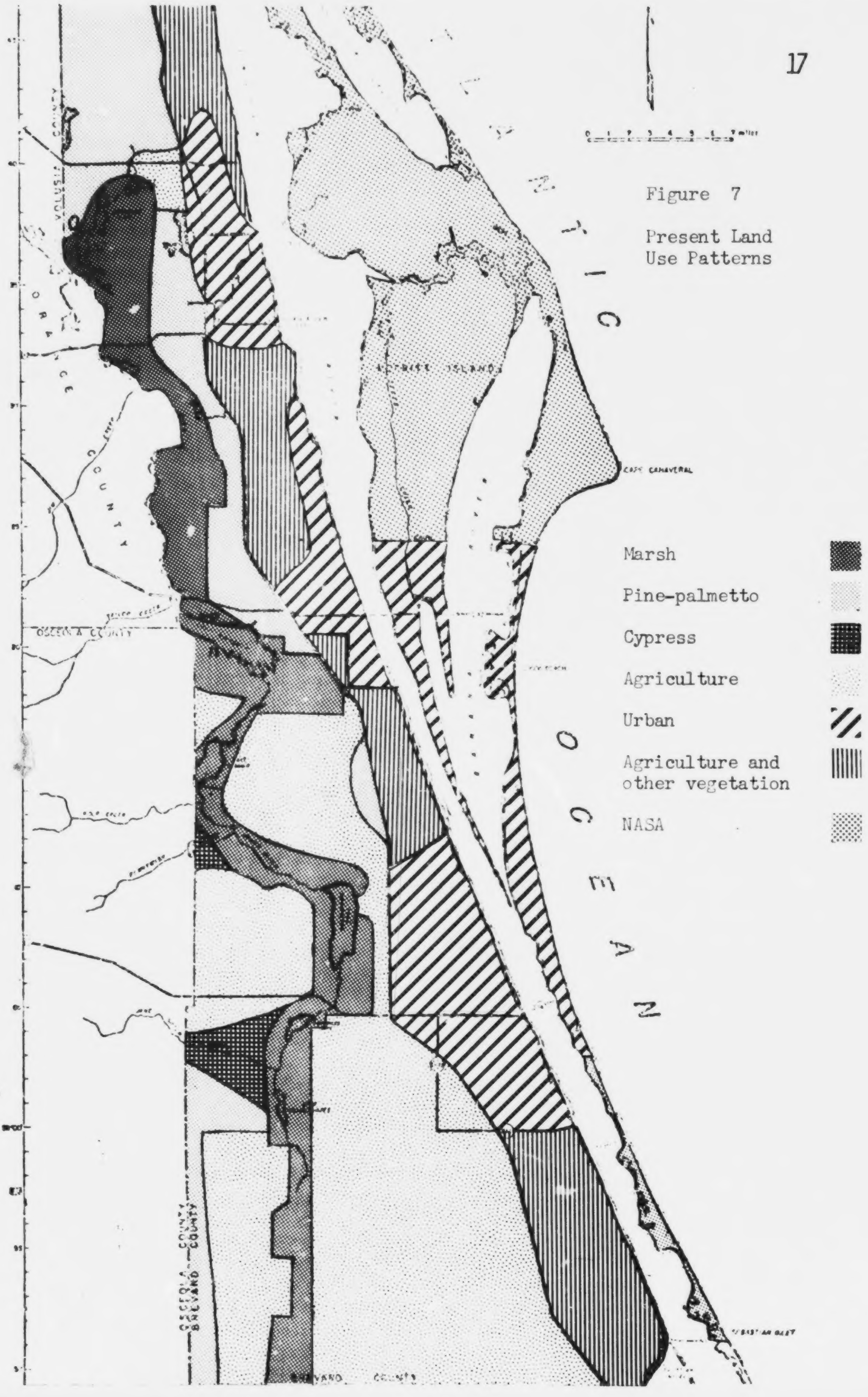


Figure 7

Present Land Use Patterns

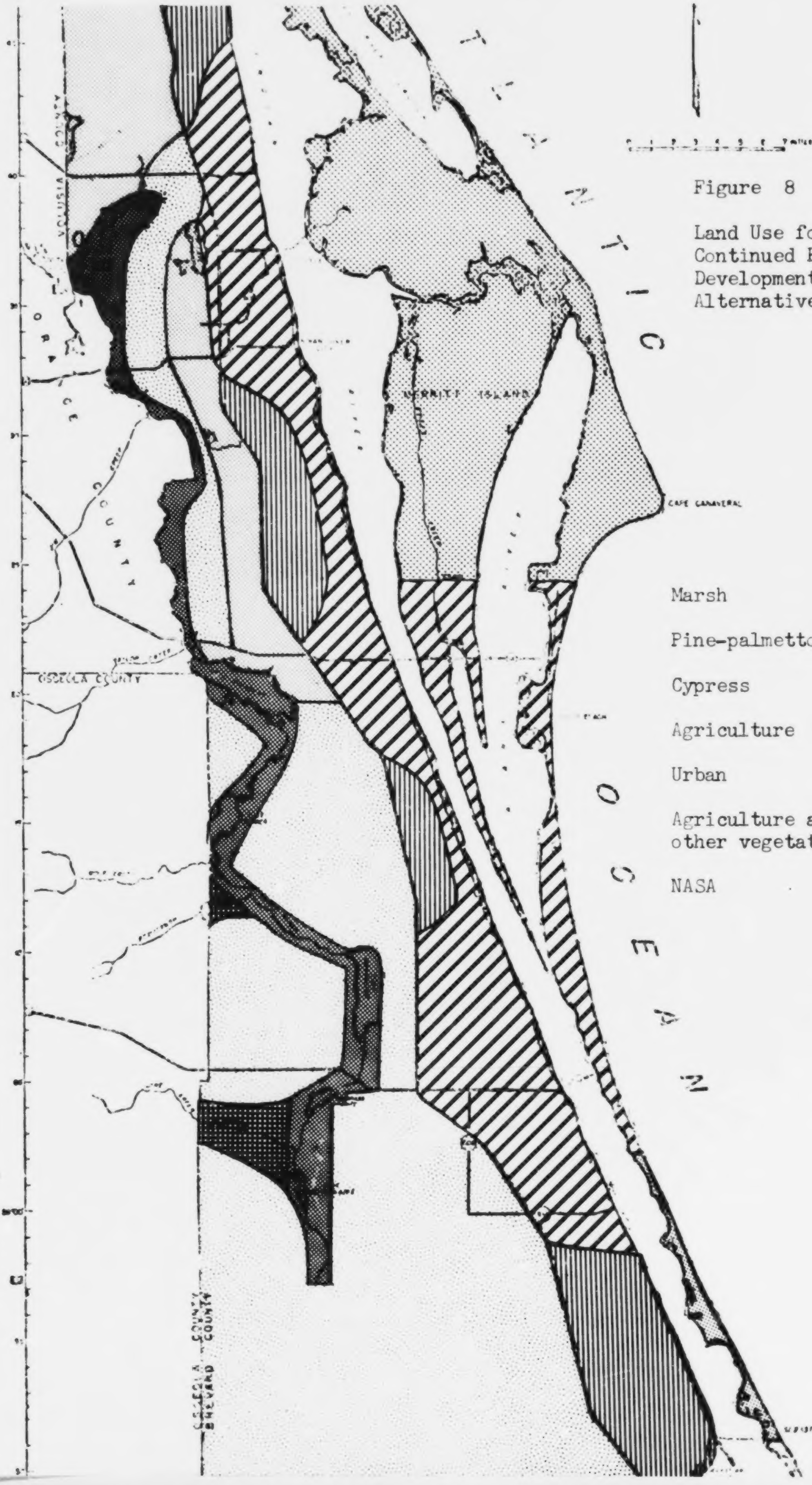


Figure 8

Land Use for Continued Private Development Alternative

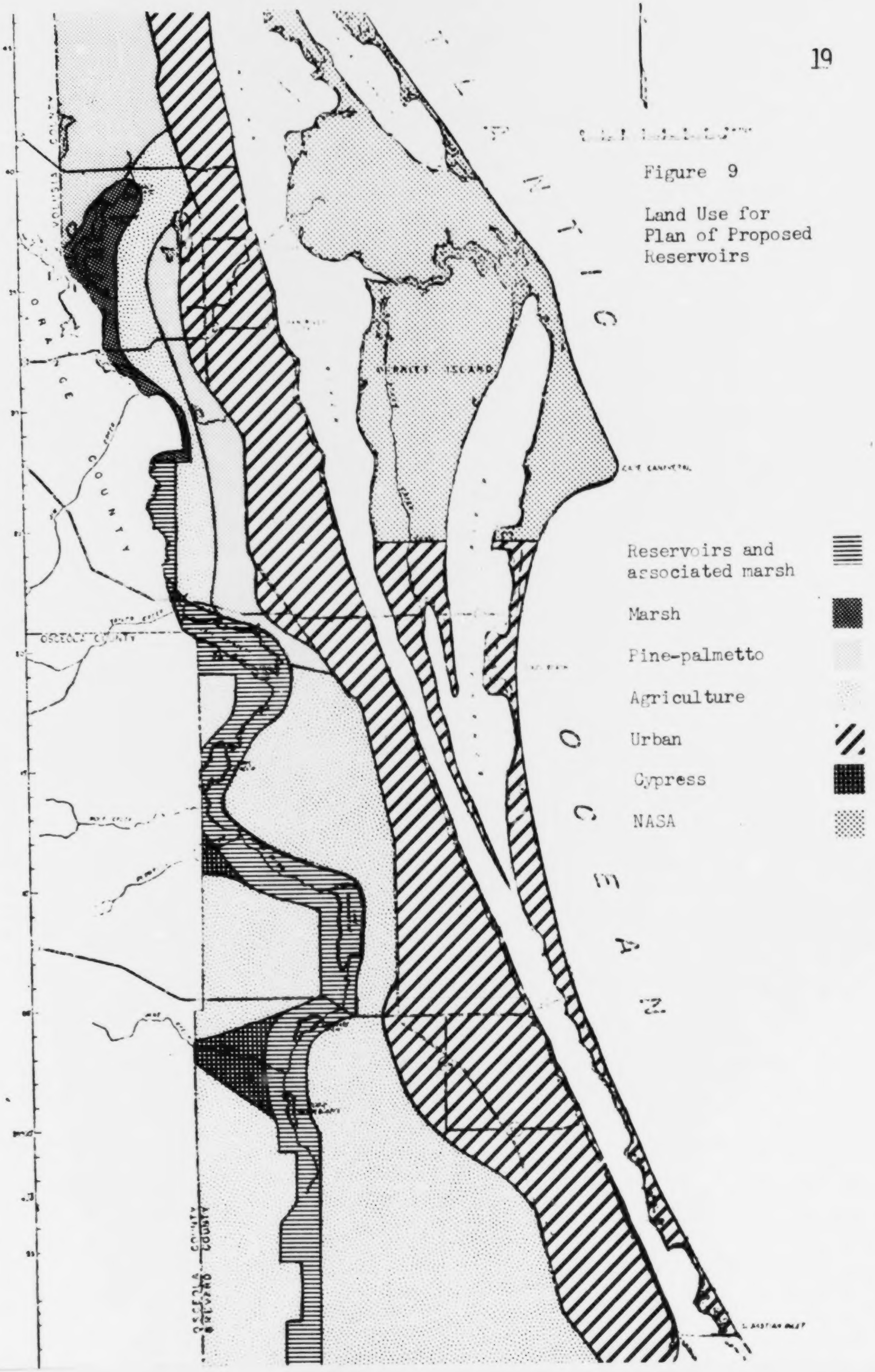


Figure 9

Land Use for Plan of Proposed Reservoirs

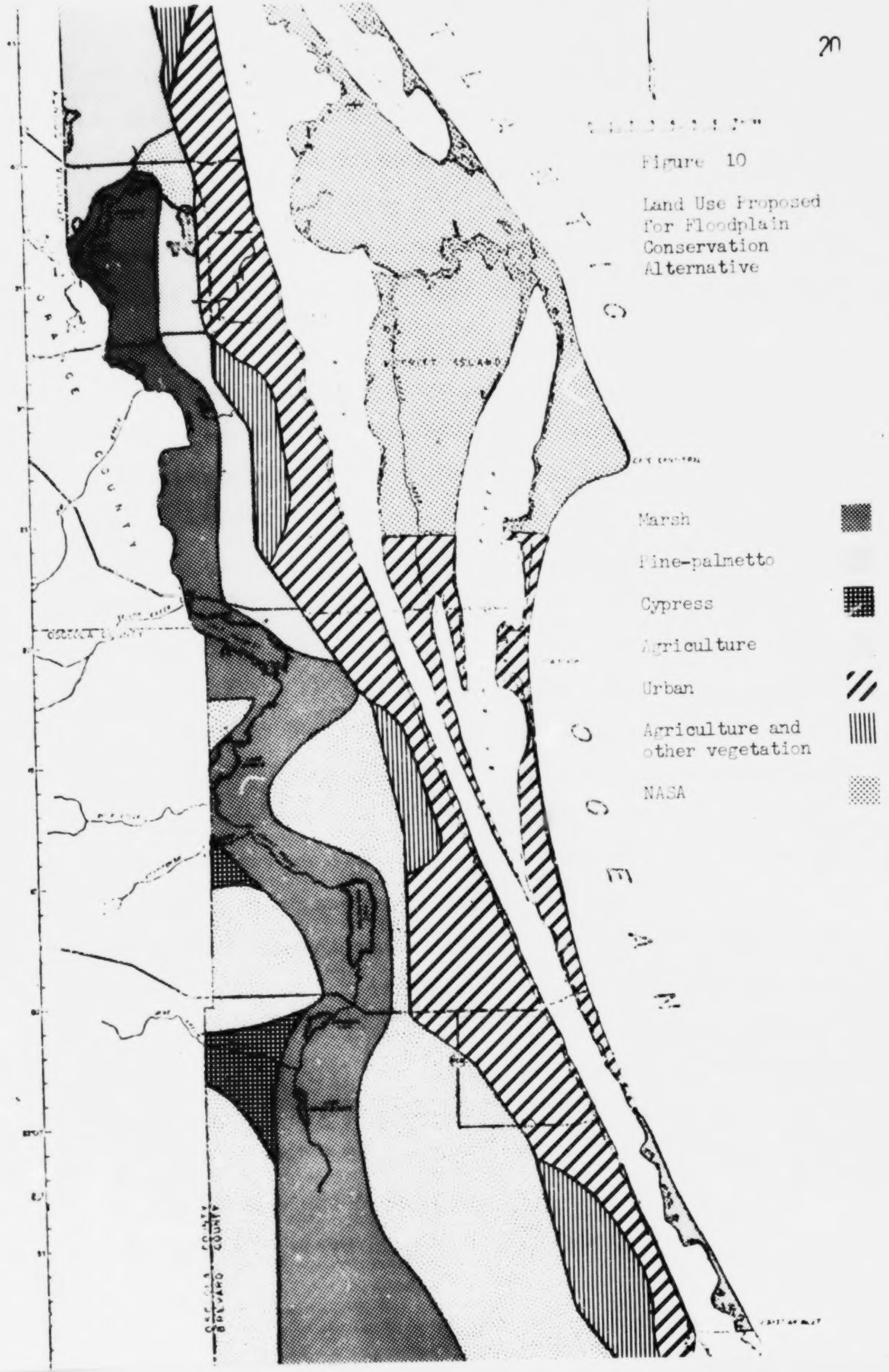


Figure 10

Land Use Proposed for Floodplain Conservation Alternative widely considered (Wharton, 1970; Steward, 1970; Odum, Littlejohn, and Huber, 1972) as a partial means to maintain water quality.

Since the historic data indicate that far more water was present in the lakes and floodplain, this plan would provide urban water requirements without new construction in the valley. The urban development is restricted to the higher elevations east of I-95.

METHODS

The general plan of this evaluation study was to determine the main patterns of energy flow controlling value in the St. Johns area and to calculate the magnitudes of work of these patterns. The main systems by which value is developed are the marshes, the river, the reservoirs, the agriculture, and human settlements. Water is a main and often limiting factor in the Florida region, and alternatives for management and water use are the principle differences affecting water value distribution. Models were developed to show water and other principal factors and pathways of value due to work of nature and man. Field studies were made to learn the effects of water levels on vegetation and rough computer simulations were run to estimate patterns of change due to water management action on water levels.

Productive energy flow rates per year were calculated for the main types of land use areas and their interactions in the situation now and in the situation estimated to follow some proposed water management changes (see also Odum, Littlejohn, and Huber, 1972). Since some of the procedures used are fairly new and becoming operational during the study, the procedures are given in a numbered list as follows:

1. First a map was prepared for each of the areas to be evaluated, and the boundaries of main types of subsystems were out-

lined with the help of aerial photographs. Defined in this way were vegetation types, agricultural zones, urban patterns, principal reservoirs, and principal river channels. Anticipating overall calculations, care was used to keep the categories few and the detail of definition within practical means for computation. In other words, macroscale viewpoint was maintained.

2. Next, an energy circuit model diagram was drawn for each area including the important variables such as water storage and water flows. This diagram has the pathways of interaction of the subsystems which generate values over and beyond those inherent in the original system. It has exports, imports, power sources, exchange flows of cars, population, money, etc. The energy diagram is a means for synthesizing the parts, processes, concepts, and ideas of many people as to the possible factors affecting the regional system.

3. Next the relationship of water level to vegetation, agricultural development, and developing urban potentials was examined with field studies to define which water level regimes contribute to each type of land use system (natural and managed). Data were obtained so that water level predictions could be translated into vegetation type so that changes in subsystem could be determined.

4. The part of the model concerned with the main flows of water was isolated from the overall model and put on analog computer to simulate the rise and fall of water levels and rainfall with various proposed management alternatives. With the water levels predicted by the model and by the field work, means are available for estimating acreages according to water level predictions that are compatible. A table of system acreages was made for each contingency.

5. Next, energy flow calculations were made for the main energy flows of each model. Energy flow in gross biological produc-

tion was multiplied by acres of each subsystem. To do this accurately data were required on gross photosynthesis or respiration of each of the subsystems. Data on the productivity of the marsh and rivers were obtained during this study. Data from the literature were used for the other subsystems. These natural energies are the sum of the total metabolism per unit area for each subsystem. Energy from nature directed toward building and maintaining plant communities, soil structures, and aquatic communities was measured in terms of the gross production (or metabolism) of that ecosystem. Estimated or measured annual work (metabolism) done by each subsystem was tabulated (see column A in Table 1). The area of each subsystem or land use system (column B) was multiplied by the annual work (column A) done by that subsystem to give the annual regional work of that subsystem (column C). The general land use maps were used as the basis for this calculation of the energy per system in the region.

6. Where important, other sources of concentrated energy contributing work such as that in winds and river flows were calculated. These and the photosynthetic energy make up most of the large natural energies which provide a buffer for man's activities.

7. Next, using the regional energy model that shows economic transactions, energy values were added for all purchases of fuels and electric power used in the area.

8. Estimates of work done in other areas on behalf of the area under evaluation are suggested by money payments and the work efforts stimulated elsewhere by these payments.

9. Finally, specific questions that came up in public discussion were studied with the perspectives of the comparative energies, predictions of water level, and the models.

Sample Calculation of Value for A Simple Model

An example of the procedure of calculation of value in work units from an overall simplified model is illustrated in Fig. 11a for a hypothetical town and marsh system. The area of land in marsh and city in a simplified example is shown and the energy flows are given both in the diagram and in the table. Note that in this sample calculation part of the energy flow is accompanied by money and part is not. Consider three main kinds of pathways as numbered in Fig. 11a and Table 1.

In the overall energy budget for calculation regional values (Fig. 11a) there are two main components by man, both of which contribute work to the region. For convenience, the calculation of work within the boundaries is made by calculating the energies entering to be used within. This method avoids the calculation of detailed pathways between internal parts of the system. In this small model the natural energy sources are the sunlight and the water which facilitates the conversion of light to marsh organic matter. See Pathway No. 1. The energetic value of the water is the energy of the flow it facilitates by amplifier action in producing marsh. Similarly for water used in urban growth, value is the energy flow it facilitates in use of fossil fuel.

The main energy entering the urban system is from fossil fuel (Pathway 2 in Fig. 11a and Table 1). Material goods, foods, and services also enter the system in proportion to the amount of money used in their purchase. Like water, their energy value is in the fuel flows facilitated by their use.

Money that enters a system leaves it in equal quantity as required for its balance of payments for purchased goods, services,

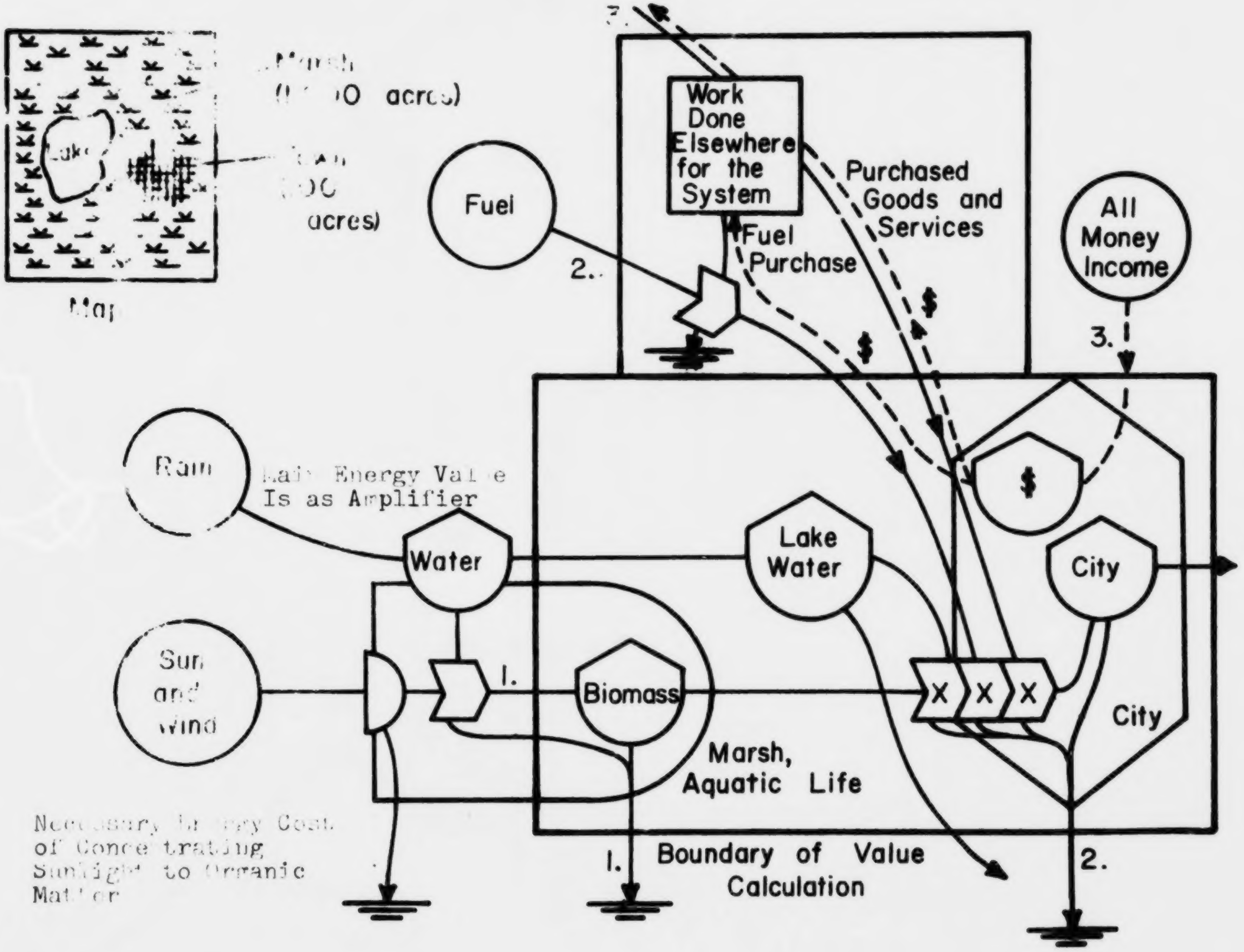

Marsh
(1 0 acres)
Lake
(0C
acres)
Map
Fuel
2.
Work Done Elsewhere for the System
Fuel Purchase
Purchased Goods and Services
$
$
All Money Income
3.
Rain
Energy Value Is as Amplifier
Water
Lake Water
$
City
Sun and Wind
1.
Biomass
X
X
X
City
Marsh, Aquatic Life
Necessary Energy Cost of Concentrating Sunlight to Organic Matter
1.
Boundary of Value Calculation
2.

Fig. 11a. [illegible] Energy Budget Model for calculating annual work values in Brevard County

Table 1

Sample Calculation for a Town of 700 Persons

		A	B	C	D
				(A + B)	(C x 10^{-4} $/kcal
Pathway No. in Fig. 11a	Subsystem	Area Acres	Value 10^6 kcal/ac/yr	Total Work 10^{10} kcal/yr	Dollar Equivalent 10^6 $/yr
1	Vegetation and Aquatic life:				
	Marsh	1000	250[a]	25	25
	City Vegetation	50[b]	24.8[a]	.124	.124
	Lake life	50	33[a]	.165	.165
	Subtotal			25.289	25.289
2	Fossil fuel to town			5.11[c]	5.11
	Total value in area			30.399	30.399
3	Goods and services-result of work elsewhere on behalf of the system			2.45[d]	2.45

[a] Producitivity per acre estimated from sample plots and field measurements.

[b] Fifty acres of vegetation and 50 acres with buildings and paving.

[c] Obtained from 2.0×10^5 kilocalories per person per day (Singer, 1970) times 700 persons times 365 days/year.

[d] Obtained from estimated per capita income of $3500 per person per year times 700 persons. This value is not included in the total (see text).

and including the work of bringing in fuels. In our procedure these energy expenditures elsewhere belong to the economies of other areas even though the products that are imported have high value and are necessary in facilitating energy flow when they are brought into our area. Pathway 3 in Fig. 11a indicates the work done outside the area in developing the purchased goods and services that are delivered to the area. The pathway of goods and services shows the role these have as amplifiers in releasing the energies of the city.

Water as an increasingly critical material carries some energy value in itself (slight energy due to its low elevation in Florida, additional energy due to its chemical state relative to its uses). However, the main value that water carries in these regions is in its ability to make possible (amplify) such processes as marsh growth, agriculture, and urban life (this property is called a high energy amplifier value). Thus the value of the water is the work facilitated. The pathway drawn in the models shows the flow of water as an important energy flow if it terminates in an energy rich process interacting with sunlight or fuels. In Table 1 the energy amplifier value of water on the combined natural and urban work is 63 x 10^6 kcal per acre foot of water (obtained by dividing total energy flow by total volume of water in the area of interest.

An Energy-Dollar Conversion for Perspective

In the economy of the nation as a whole the total circulation of money, the Gross National Product (GNP) is accompanied by a total work done in the economy which is approximated roughly by the total fuel consumption of the nation. The ratio of these two annual rates is about 10,000 kilocalories per dollar. For every dollar that circulates through the economy, about 10,000 kilocalories of work is done in various actions dispersed through the system. Since most people have a feeling about the value of a dollar and the amount of useful activity its circulation generates, we may find it useful to convert our energy work estimates to 'dollar equivalents' thus helping the readers visualize the magnitudes. This procedure allows the enormous work of nature's systems in behalf of our survival to be recognized on familiar scales. The dollar equivalents for natural works suggest the amount of money we would have to pay someone to do the things nature does for us if it were possible for humans to do it as well. In column D of Table 1, dollar equivalents are calculated for the example diagrammed in Fig. 11a.

The conversion of dollars to energy is not necessary for our calculation of total energy, since both natural and urban energy is calculated directly in kilocalories of work. For convenience the work can be convered to dollars to allow comparison in economic terms. However, if the fossil fuel energy on which we all live becomes more expensive this conversion of approximately 10,000 kcal/$ is no longer valid. Another conversion must be found and thus any dollar conversion (or cost benefit analysis) which assumes a constant energy to dollar ratio (price) is probably incorrect.

Sensitivity of the Model to Changes in Fossil Fuel Availability and Economic Income

A critical feature of the system and its evaluation is the fuel delivered per unit of money expended. If there are general rises of fuel costs outside (due ultimately to the worldwide decline of concentrated sources), there is less energy available to the area per unit dollar spent. If the area is energy short, wasteful, or misuses its resources it delivers less services per dollar as compared to competitive areas and its ability to obtain money for further energy purchases declines and growth may stop.

If the cost of a kilocalorie of fuel increases due to the increasing difficulty in obtaining suitable fuel, then one obtains less energy per dollar; more dollars must be spent to do the same work. For example, if fuel sources are getting more dilute and it costs more to process them, then the price of gasoline may go from 40¢ a gallon to 80¢ a gallon, however, the automobile still gets only 15 miles to a gallon and so more money must be spent to go the same number of miles (or do the same amount of work). In other words there is inflation and the true value of the dollar is less. This trend makes the natural environment worth more dollars since its proportionate role in the work of a dollar is greater. The natural amplification of an amount of fuel is the same but the dollar cost is greater.

In Fig. llaand Table 1 the natural work (Pathway 1) acts as an amplification on the urban process (Pathway 2) and helps harness the fossil fuel energy in pathway 2 in its interaction in the city. The monetary costs of the fuel, goods, and services are shown in Pathway 3. Money flows through the system as payment for the human contributions. If the fuel costs are doubled and the income of the region does not increase, then the region is able to buy fewer fuels, goods and services and so the total energy of the region decreases and the proportion of the work done by nature increased (or has greater value). This is demonstrated in Table 2.

Converting this to dollars and using the current approximation (before the price of fuel increases) nature is worth \$25 x 10^6
But if the dollar/energy ratio has changed on the national scale (due to the increases in price) then a new conversion will be in

Table 2

Sample Calculation Showing Increasing Value of Nature to a Region as the Fossil Fuel Energies Decline

	Income (Pathway 3)	Energy from Nature (Pathway 1) 10^{10}kcal/yr	Energy from Fossil Fuel (Pathway 2) 10^{10}kcal/yr	Sum of Energy 10^{10} kcal/yr	Proportion of Total Energy to Nature	Conversion of $/Energy	$ Equiv. of Nature 10^6 $/yr	$ Equiv. of Total 10^6 $/yr
Before increase in price of fuel	2.45	25.289	5.11	30.39	83.1%	$\frac{10{,}000\ \text{kcal}}{\$}$	25.289	30.39
After increase in price of fuel	2.45	25.289	2.55	27.84	90.8%	$\frac{5{,}000\text{kcal}}{\$}$	50.578	55.68

existence. In this calculation (Table 2) we have used 5,000 kcal/$. This makes nature's value double in economic terms.

An example of this increased value of nature may be a city which uses a marsh for tertiary treatment of waste rather than a tertiary sewage treatment plant. With increased fuel costs, the city will have higher electric rates and higher costs to run a tertiary treatment plant. A city which uses a marsh for tertiary treatment is then saving the original cost of the plant and when the fuel costs increase, it is saving proportionately more money. Thus, the marsh has both a higher dollar value and a higher proportion of the total energy value. The same parallel holds for all services that nature performs. Thus, if incomes are work dependent, as fuel availability decreases (and fuel monetary costs increase) the natural environment has more relative value.

In the calculations for Brevard County we avoided conversion of dollars to energy because we cannot predict what the new conversion will be and it is not valid to use the current conversion which assumes a continued supply of cheap oil.

Transition Losses

The calculation of energy value per year of various alternatives was made without regard to the interruptions during the changeover of one land use system to another. A number of years of transition may be required for readaptation of vegetation, land forms, soils, and loss of accumulated structure such as peat, forest, buildings. Any cost benefit decision process should consider the losses associated with the transition processes. This may be relatively short in some aquatic ecosystems, but very large for forests, urban communities and agricultural investments. Some estimates of the losses need to be calculated and prorated over the period of planning being considered. Costs of construction are additional transition costs to be included.

Any proposed change must have a sufficiently high energy value to make up for those losses sustained during the transition of one system to the new one so that the region will retain a competitive position both economically and energetically. The magnitude of the energies lost from transition interruptions can be estimated if some idea of the sag can be estimated as in the example in Fig. 11b. This loss of value production may be large for a year or two but be more than counteracted by increased values when both are prorated over longer periods of time. If there are repeated changes and interruptions, then there are repeated losses from transition adaptations. Since this report is mainly aimed at comparing alternative land and water uses themselves rather than the timing of changes and interruption, these negative losses have not been added. For any short time consideration they should be subtracted; for long range ultimate considerations they become small.

Simulation of Value with a Simplified Model of Interaction of Natural and Fossil Fuel Energies

Whereas most of the evaluation effort of this report concerns the work flows for five selected combinations of land and water use, a computer simulation calculation was also made for an overall simplified energy model of man and nature interactions. The model, like the more complex inventory model in Fig. 12, has growth of natural energies, urban and agricultural development using natural and fuel energies, and those work values developing from the interaction of a natural and urban structure such as tourism and retirement.

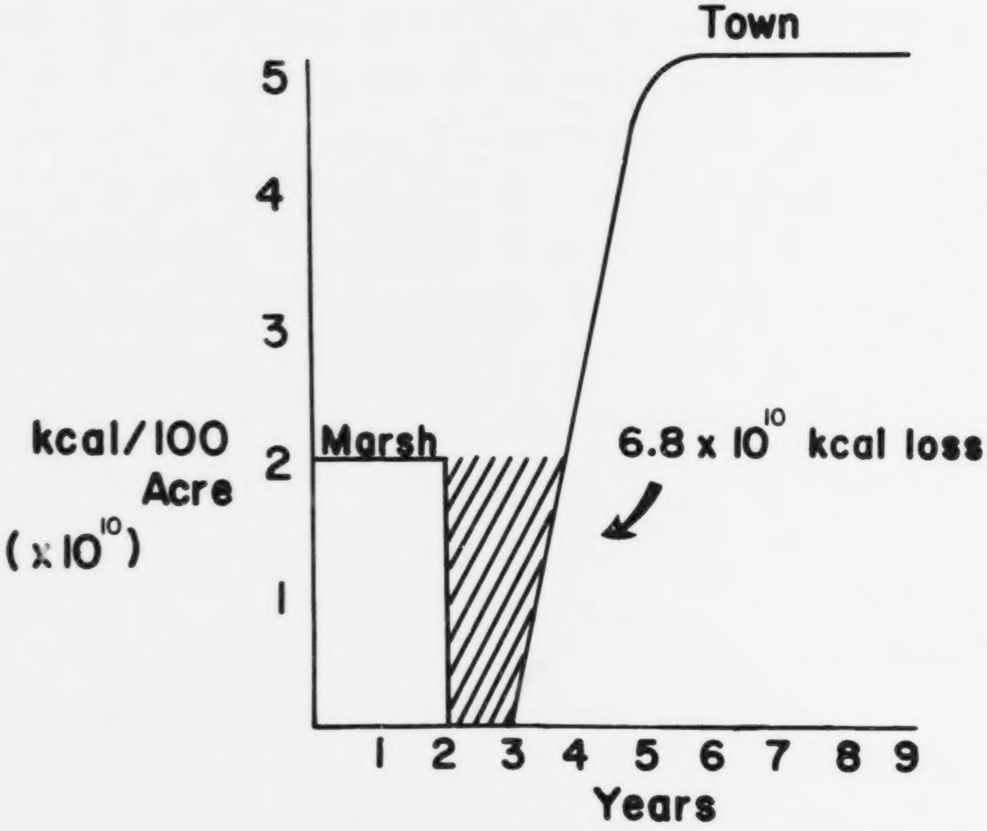


Figure IIb Example of Value lost to Region. (Shaded area is a transition period.)

Two previous simulations of this model showed that it produces an optimum ratio of developed land to undeveloped land in which the values (work contributions to the economy) are maximum. Substituting values from Brevard County, a set of graphs was produced for various ratios of developed and undeveloped land.

RESULTS

Models for Brevard County

Using the principles illustrated in the sample Figure 11a a model to summarize the interactions between the natural subsystems, agricultural subsystems, and the general economy of Brevard County is presented in Figure 12. Each of these subsystems is linked by both energy flow and water flows. The energy flows are the numbered pathways (1-15) and correspond to the subsystems of interest. The energy flow pathways are used to evaluate each of the energy flows within the region and to give a perspective on the relative amounts of work contributed by the various components of the region. The sum of all the work flows within the region may be defined as the total regional metabolism. This is shown in Pathway 14 at the bottom of Figure 12 as the total work flow.

The flows of money are dashed and flow counter to work or energy flow where a purchase or sale has taken place. Money inflows also enter with NASA and related payrolls, capital investments, and the savings of tourists and retirees. Only flow 15 is not a part of the energy flow within the area. It is the work done in areas outside to develop the goods that are purchased and brought into the system as a necessary component of the general urban process. The urban process is simplified into a reaction of flows of fuels, services, water, land use, and use of structure. The region delivers values to the outside including space knowledge, farm products, tourist fulfillment, and river water among others.

Figure 12 indicated calculations made in Tables 3-7 for 5 alternatives. The area in each type of land use and the amount of

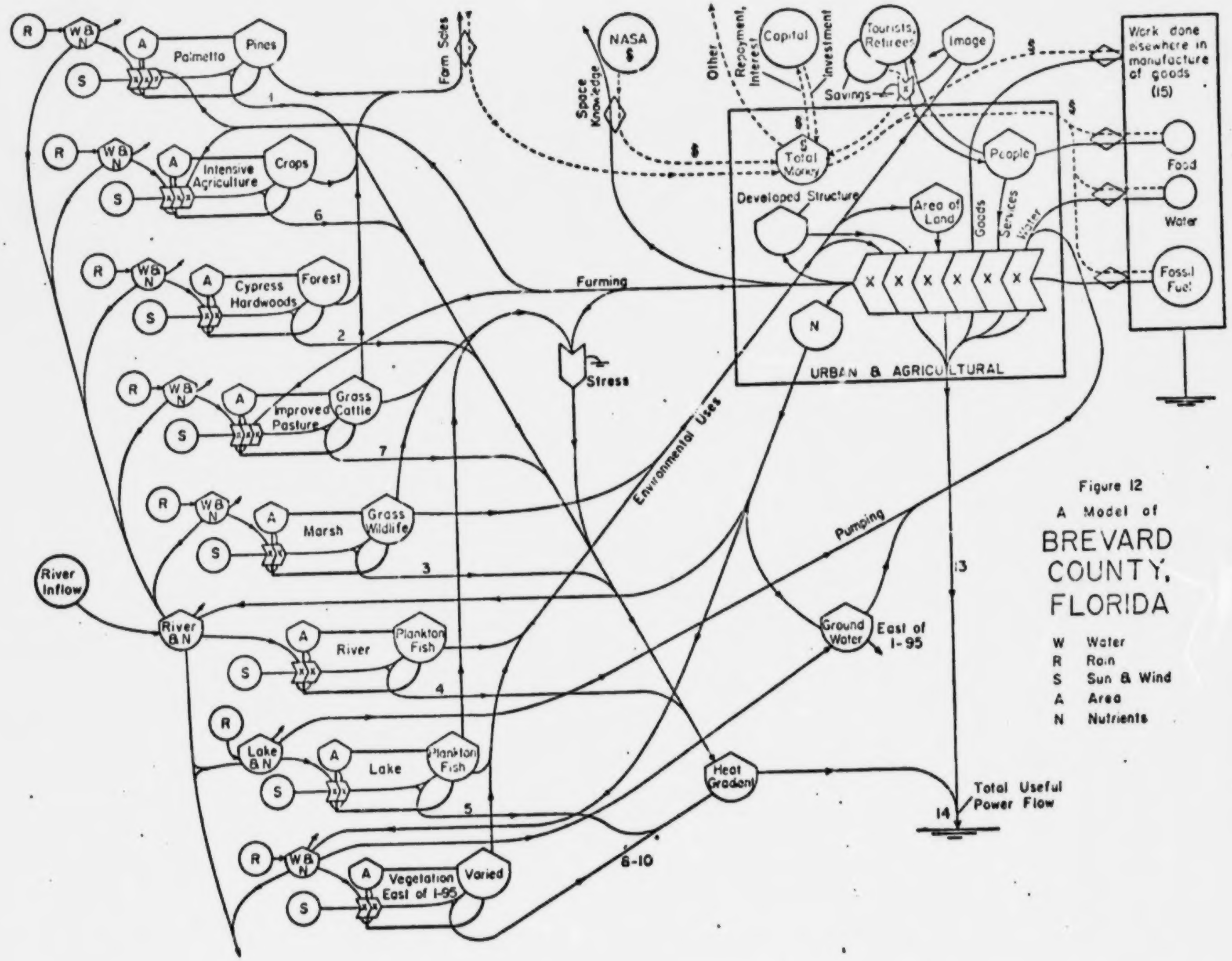


Figure 12

A Model of

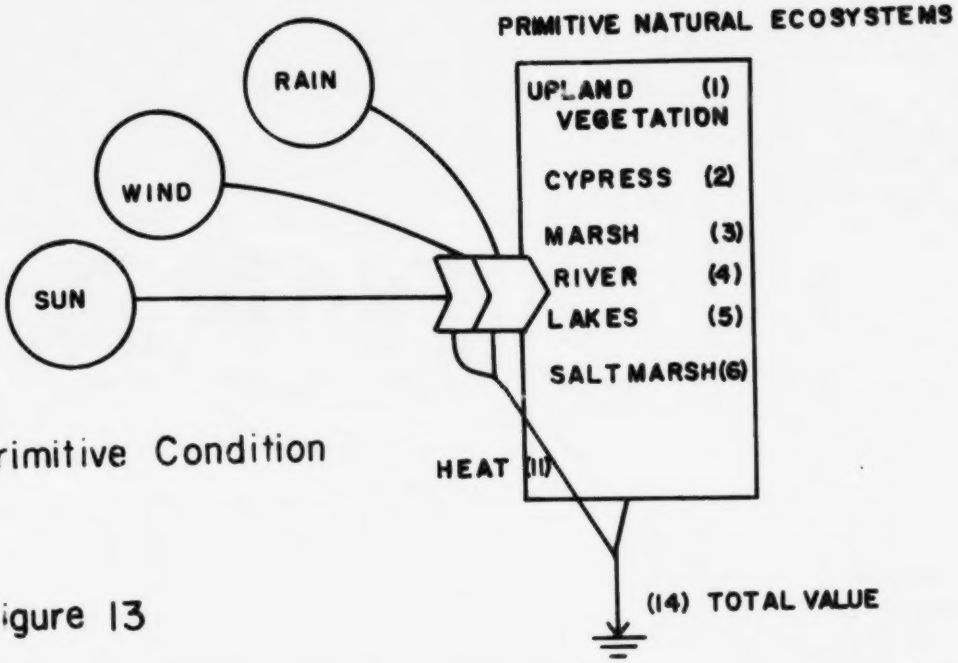
BREVARD
COUNTY,
FLORIDA

W Water
R Rain
S Sun & Wind
A Area
N Nutrients

available water determines the productivity of each subsystem. The area in each type of land use was derived from aerial photographs and represented by the land use maps in the introduction. The urban energies are estimated from the total fuels. The outside wor in support of the area is estimated from a dollar/energy flow ratio approximation for the U. S. economy. This is roughly equivalent to 10,000 kcal/$.

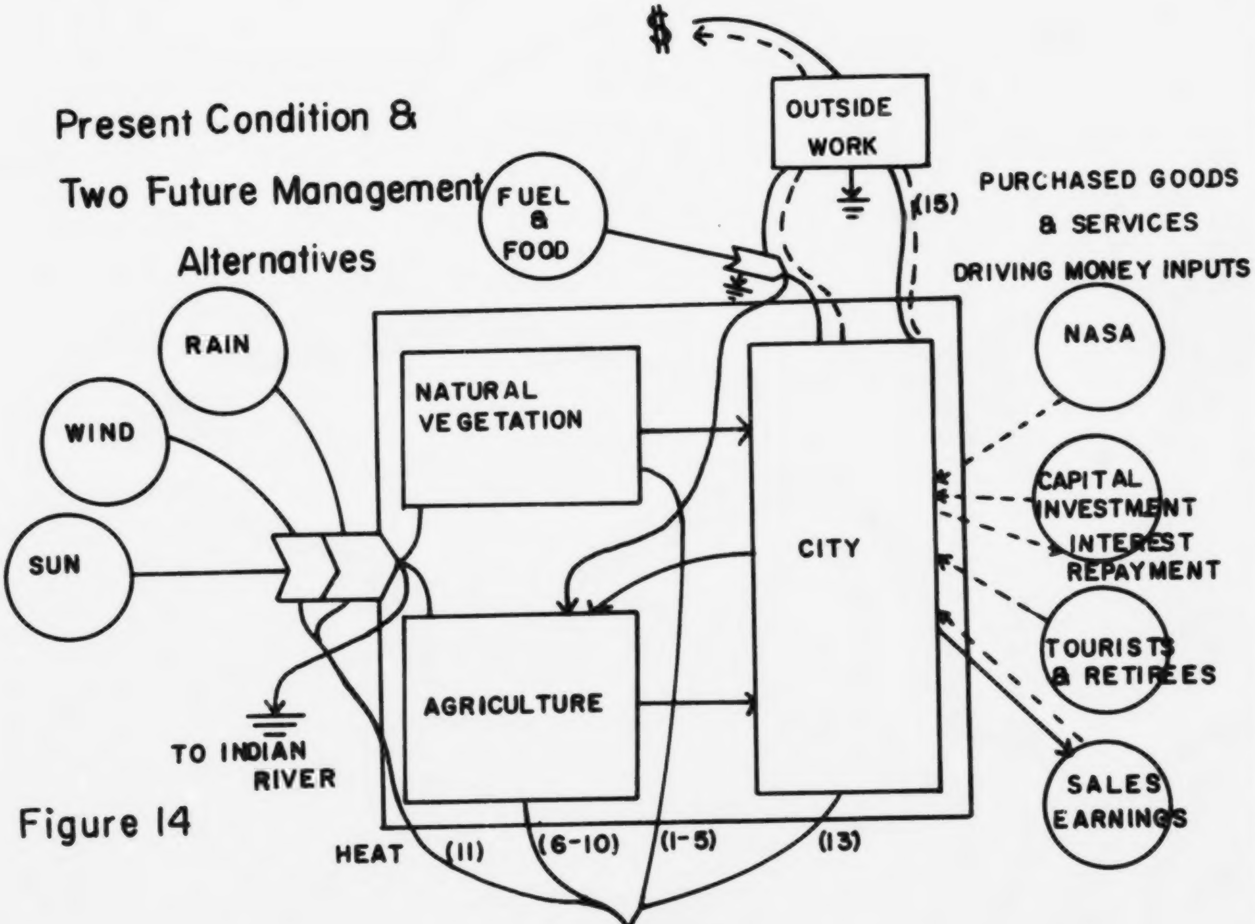
For the purposes of this model, flows that are circular within the subsystems such as the wages, internal sales, electric power conversion from fuel and its subsequent use are not detailed or evaluated when they are within the county. The energy approach allows one to compartmentalize in this way as long as one has all the important inflow and outflows evaluated.

An abbreviated diagram is given (Figures 13-15) for each alternative with less detail than that in Figure 12. The major determining characteristics and differences between alternatives are presented in the energy diagrams.



Primitive Condition

Figure 13



Present Condition & Two Future Management Alternatives

Figure 14

Proposed Floodplain Conservation Plan

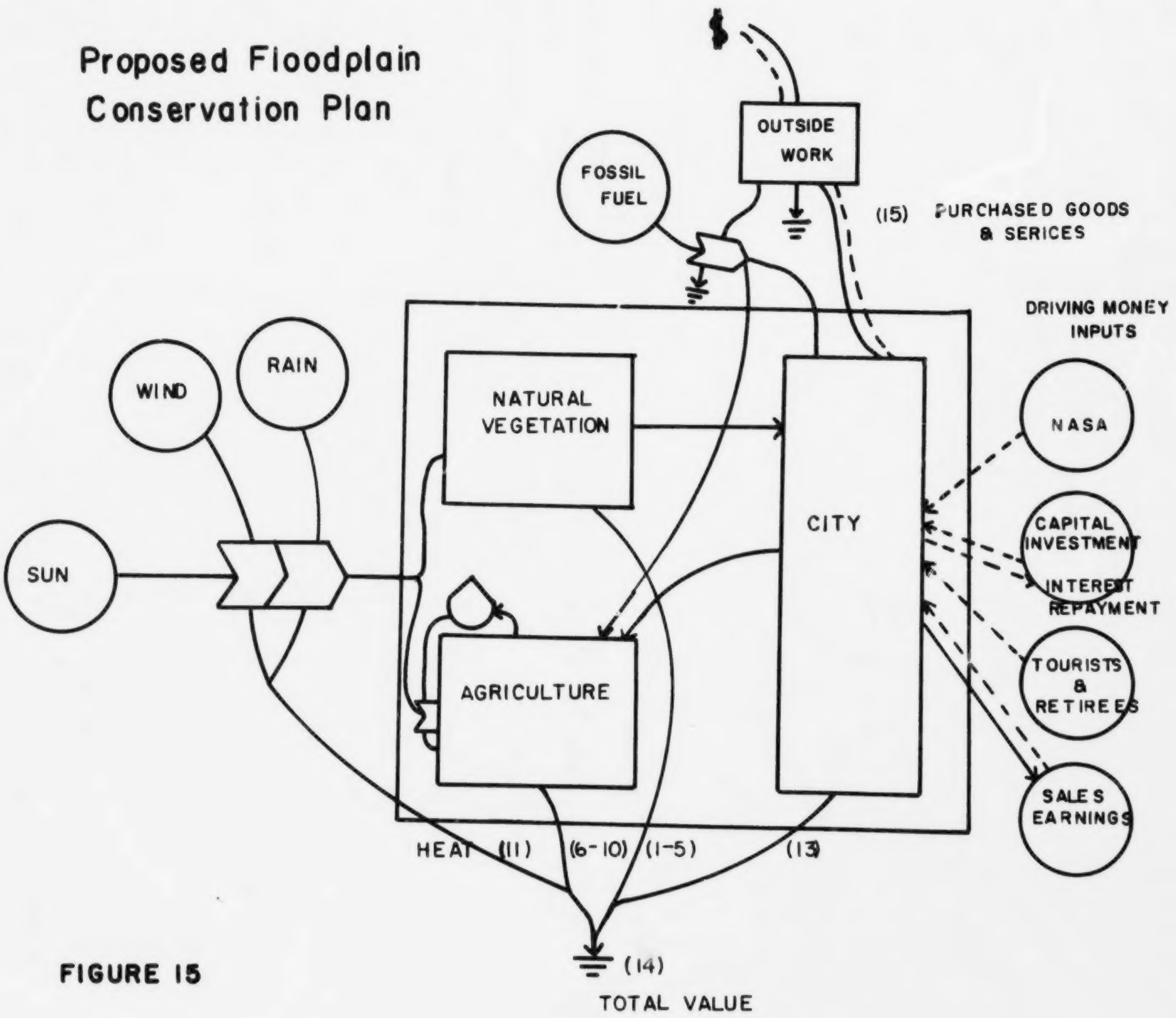


FIGURE 15

Energy Value Tables
Developed Using an Unlimited Growth Potential
(Unlimited Energy & Money)

Tables of values calculated for each of the five possible alternatives in Brevard County are given as Tables 3-7 with the same methods used in the sample calculation (Table 1; Fig. 11a). Each major pathway in the diagrams has a corresponding line in the energy value tables. The amount of work in kilocalories was calculated for each pathway. The details of calculations in the tables are indicated in footnotes.

Table 3

Energy Value Calculation for the Primitive Condition

Pathway	Name of Energy Flow	Annual Work[a] Million kcal/acre/yr of that Type		Area of System[b] Thousands of Acres	Region's Annual[c] Work 10^{12} kcal	$ Equivalent for Human Work Mil. $/region[d]
Natural systems west of Interstate 95						
3	Marsh	242	e	218	52.75	
1	Pine flatwoods	41.2	f	113.8	4.69	
4	River	19.0	g	3	0.06	
5	Lakes	13.6	h	20	0.27	
2	Cypress hardwoods	103.	i	25	2.57	
East of Interatate 95						
1	Pine flatwoods	41.2		265	10.92	
6	Salt marshes	139.9	j	30	4.20	
Subtotal				674.8	75.45	7,545
Other contributing flows:						
11	Heat gradients on land from sun's heating	58	k	654	37.93	
Total					113.39	11,339

Footnotes to Table 3

* Values generated per year are calculated as the work done by the process of man and nature during that year.

a. Estimates or calculations of gross primary production are from field measurements or taken from published literature.

b. Areas are calculated from aerial photographs.

c. Values in column C are calculated as the product of column A and column B.

d. The annual contribution in dollar equivalent was estimated roughly by dividing column C by the ratio of the GNP to fuel usage in the U. S. economy (10,000 kilocalories per dollar).

e. Marsh - gross productivity was measured in the field; see Bayley et al, 1973. The average value of all marsh plants obtained during the wet season was 33.5g C/m^2/day. Values for the dry season have not been measured yet but production was assumed to be proportional to solar input. Energy per langly of sun's energy was integrated over the year to obtain a yearly average of 20.5g C/m^2/day.

f. Pine-Palmetto - pine metabolism was determined to be 2550 g/m^2/yr (3.5g C/m^2/day). This was multiplied by 8 kilocalories per gram of carbon and converted to an acre basis (Woodwell and Whitaker, 1968).

g. River - The productivity of the aquatic ecosystem was measured during this study: 13.2 kcal/m^2/day (3.3 gO_2/m^2/day).

h. Lakes - The productivity was measured during this study: 9.2 kcal/m^2/day (2.3 gO_2/m^2/day).

i. Cypress - hardwoods - A value was estimated from tropical rain forest gross production (Odum, 1970) and reduced to half for half year deciduous period: 70 kcal/m^2/day (8.73 g C/m^2/day).

j. Salt marshes - A value was taken from Georgia salt marsh measurements by Teal (1962): 34,580 kcal/m^2/year (11.85 g C/m^2/day).

k. 4000 kcal/m^2/day times the Carnot ratio of 3/300 for a gradient of 3 in the lower zone of air.

l. Calculations from unit model water budgets (Bayley et al, 1973).

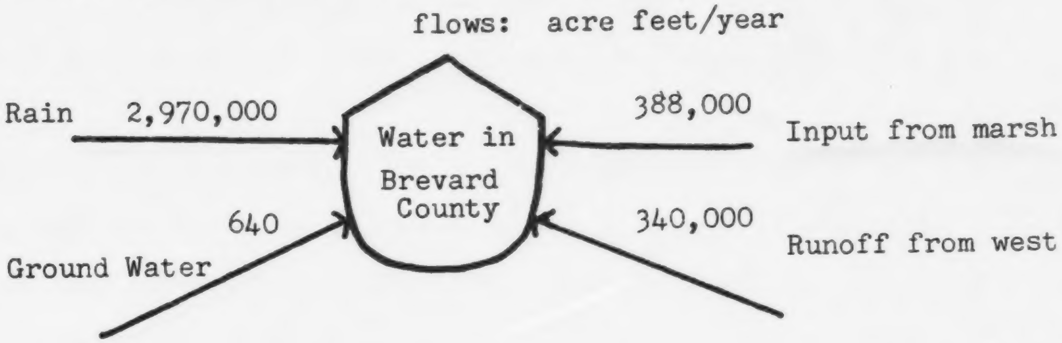


Table 4

Energy Value Calculations for 1970 Conditions

Pathway on Figure	Name of Energy Flow	A Annual Work[a] Million Kcal/Acre/Yr of That Type		B Area[b] of System Thousands of Acres	C Region's Annual Work, 10^{12} Kilocalories	D $ Equivalent[d] for Human Work Million $ Per Region
Natural Systems West of I-95						
3	Marsh	233	e	88.	20.50	
1	Pine Flatwoods	41.2	f	109.6	4.51	
4	River	19.0	g	3	0.06	
5	Lakes	13.6	h	15.	0.20	
2	Cypress hardwoods	103	i	17.4	1.79	
7	Improved pasture	80.4	m	124.8	10.03	
6	Intensive agriculture	51.	l	20	1.02	
8	Urban and roads	10	j	2	0.02	
East of I-95						
9	NASA area	47.6	n	104	4.95	
8	Urban area	21.5	o	45	0.97	
6, 7	Agriculture	75.5	p	67	4.79	
10	Other vegetation	41.2	q	79	3.25	
Subtotal:				674.8	52.10	5,210.
Other Contributing Flows:						
11	Heat gradients on land from sun's heating	58	k	654	37.93	
12	Natural Subtotal:				90.03	
Urban Energies:						
	Bunker C fuel	3.5×10^4 kcal/gal[s]		2.24×10^8 gal/yr[r]	7.84	
	Gasoline	3.2×10^4 kcal/gal[t]		1.02×10^8 gal/yr[r]	3.26	
	Diesel fuel	3.5×10^4 kcal/gal[s]		2.3×10^7 gal/yr[r]	0.80	
	Natural gas	278 kcal/cu ft[w]		8.7×10^9 cu ft/yr[r]	2.42	
	Food	9.12×10^5 kcal/cap/yr[u]		230,000 people[x]	0.21	
13	Urban Subtotal				14.53	
14	Total				104.56	10,456
15	Work done elsewhere paid for with purchases	$535. $\times 10^6$				

Footnotes to Table 4

a.-d. Same as Table 3.

e. Productivity of Spartini bakeri, the main marsh plant in both the lower and higher elevations, was measured during the wet season as 27.3g C/m^2/day, and the solar energy was an average 570 langleys. Assuming production proportional to solar energy the yearly average was 19.7g C/m^2/day by integrating the yearly solar energy.

f.-i. Same as Table 3.

j. Urban and roads - the value used was from p. 51 (Odum, 1971) minus 80% for buildings and paving (0.85g C/m^2/day).

k. Same as Table 3.

l. Productivity of citrus tree taken as 4.3g C/m^2/day. Value taken from Heinicke, A. J. and N. F. Childers (1937) for an apple tree and adjusted for solar energy input.

m. Pasture - Productivity of pasture grasses was measured during the wet season as 10.4g C/m^2/day. Yearly production was assumed to be proportional to solar energy and the grams carbon produced per langly of energy was integrated over the yearly solar cycle to obtain an average 6.8g C/m^2/day.

n. NASA area - the Nasa area consists of 25,000 acres of saltmarsh at the same value as j. in Table 2; 24,000 acres of buildings and paving at the same value as j. above; and 55,000 acres of sparsely vegetated area at 22 x 10^6 kcal/ac from Golley (1965) and Odum, Littlejohn and Huber (1972) 4.04g C/m^2/day.

o. Urban area - The value was an average of 50% residential area at a value taken from p. 51 (Odum, 1971) minus 30% for buildings and paving and 50% commercial area at the same value as in j. above. The result was 1.82g C/m^2/day.

p. Agriculture – This area was 70% pasture at the same value as in m. above and 30% citrus at the same value as in l. above. The result was 6.05g C/m^2/day.

q. Other vegetation – This area is primarily pines and palmetto at the same value as f. in Table 2. (3.5g C/m^2/day).

r. Data obtained from Port Canaveral, Brevard County Planning Department, Florida Power Corporation and City Gas Company.

s. Encyclopedia of Chemistry:

$$\frac{19{,}000\ \text{BTU/lb}}{4\ \text{BTU/kcal}} \times 7.4\ \text{lb/gal} = 35{,}000\ \text{kcal/gal.}$$

t. Encyclopedia of Chemistry:

$$\frac{20{,}800\ \text{BTU/lb}}{4\ \text{BTU/kcal}} \times 6.15\ \text{lb/gal} = 32{,}000\ \text{kcal/gal.}$$

u. 2,500 kcal/person/day x 365 day/year = 9.12 x 10^5 kcal/person/yr.

v. This is approximately equivalent to the 1970 gross sales.

w. Encyclopedia of Chemistry: $\frac{1100\ \text{BTU/cu ft}}{4\ \text{BTU/kcal}} = 278\ \text{kcal/cu ft.}$

x. Florida Statistical Abstracts, 1971: population for 1970 = 230,000.

y. Water availability: Total water input equals the value calculated for the primitive state minus man's diversions.

Diversions:	16,257 ac ft/yr	– urban water supply in Brevard Co.
	47,100	– irrigation in Brevard Co.
	144,540	–reduced input due to altered drainage patterns
	207,897 ac ft/yr	

Total input: 3,490,743 ac ft/yr

Table 5

Energy Value Calculations for Continued Private Agricultural Development in the Floodplain

Pathway on Figure	Name of Energy Flow	A Annual Work[a] Million Kcal/Acre/Yr of That Type		B Area[b] of System, Thousands of Acres	C Region's Annual[c] Work, 10^{12} Kilocalories	D $ Equivalent[d] for Human Work Million $ Per Region
Natural Systems West of I-95						
3	Marsh	116.5	e	25	2.91	
1	Pine flatwoods	30.9	f	100	3.09	
4	River	39	g	2.5	0.10	
5	Lakes	54.4	h	13	1.71	
2	Cypress hardwoods	77.2	i	15	1.16	
7	Improved pasture	60.3	m	180.3	10.87	
6	Inteisive agriculture	25.5	l	40	1.02	
8	Urban and Roads	5	j	4	0.02	
East of I-95						
9	NASA area	47.6	n	104	4.95	
8	Urban area	10.7	o	67.2	0.72	
6, 7	Agriculture	35.7	p	56.8	2.03	
10	Other vegetation	30.9	q	67	2.07	
				674.8	29.65	2,965
Other Contributing Flows						
11	Heat gradients on land from sun's heating	58	k	654	37.93	
12	Natural Subtotal:				67.58	
Urban Energies						
	Bunker C fuel	3.5 x 10^4kcal/gal[s]		3.36 x 10^8gal/yr[r]	11.75	
	Diesel Fuel	3.5 x 10^4kcal/gal[s]		3.45 x 10^7gal/yr[r]	1.21	
	Gasoline	3.2 x 10^4kcal/gal[t]		1.53 x 10^8gal/yr[r]	4.90	
	Natural gas	278 kcal/cuft[w]		13.0 x 10^9 cuft/yr[r]	3.62	
	Food	9.12 x 10^5kcal/yr[u]		343,000 people[4]	0.31	
13	Urban Subtotal				21.79	
14	Total				89.37	8,937
15	Work done elsewhere paid for with purchases	$802. x 10^6				

Footnotes to Table 5

a.-d. Same as Table 3.

e. Marsh productivity decreased by 1/2 in drained areas - 1/2 of value e. in Table 4: 9.86g C/m^2/day (Carter et al., 1973;) water table in floodplain lowered by 3 ft. since 1940's (Cox and Auth, 1972).

f. Pine-palmetto productivity decreased due to lowered water table - 3/4 of value in Table 3: 2.62g C/m^2/day (Carter et al., 1973).

g. River productivity increased due to increased nutrients - 2 times value g. in Table 3: 6.6gO_2/m^2/day (Odum et al., 1972).

h. Lake productivity increased due to increased nutrients - 4 times value h. in Table 3: 9.2gO_2/m^2/day (Brezonik et al., 1969; Brezonik, 1973).

i. Cypress productivity decreased due to lowered water table - 3/4 of value i. in Table 3: 6.55 g C/m^2/day (Carter et al., 1973).

j. Urban area productivity decreased due to lowered water table and restricted municipal pumping for lawns which require 3"/mo in the spring - 1/2 value of j. in Table 3: 0.42g C/m^2/day (USDA Agricultural Extension Service; Brevard County; Schroder and Ruelke, 1959).

k. Same as k. in Table 3.

l. Agriculture productivity decreased due to lowered water table and lack of irrigation - 1/2 of value l. in Table 4: 2.15g C/m^2/day (Schroder and Ruelke, 1959; Schneider and Childers, 1941; Ashton, 1956).

m. Pasture productivity decreased due to lowered water table and lack of irrigation - 3/4 of value m. in Table 4: 5.1g C/m^2/day (Schroder and Ruelke, 1959; DeWit, 1958; Rosenzweig, 1968).

n. Same as in Table 4.

o. 1/2 value o. in Table 4: 0.91g C/m^2/day (same as j. above).

p. 1/2 value p. in Table 4: 3.03g C/m^2/day (same as l. above).

q. 3/4 value q. in Table 4: 2.62g C/m^2/day (same as f. above).

r. Volume per year determined by multiplying 1970 values times 1.5. The factor 1.5 was determined by the water availability. It is unlikely that ample additional water could be obtained from Orange County for later Brevard County development. Therefore the county is dependent on its surface waters (St. Johns River). Determination of the amount of water available with development only:

Melbourne currently uses:

9 MGD	for 94,000 persons	- from St. Johns River
10.5MGD	for 136,000 persons	- from shallow aquifer or Orange County water
19.5MGD	for 230,000 population	

If used 75% of total low flow = 35.2 MGD. With 35.2 MGD @ 170 gal/person/day (less than Miami currently uses) a Melbourne population of 207,000 could be supported plus 136,000 for rest of county receiving other water. Total future population of 343,000 @ a density of 5.1 persons/acre (typical suburban density, Veri, 1971) = 67,200 acres of urban. 343,000 is 1.5 times 230,000.

s.-u. Same as in Table 4.

v. Monies increased by a factor of 1.5 (see r. above).

w. Same as w. in Table 4.

y. Water availability:

Total water input equals the value calculated for the primitive state minus man's diversions.

Diversions:	39,411 ac ft/yr	- urban water supply in Brevard County
	144,540	- reduced input due to altered drainage patterns
	44,100	- irrigation of 18,000 acres of pasture @ 29.4 inches of water (p. c-15, USDA, 1969)
	60,000	- irrigation of 40,000 acres of citrus @ 18 inches of water (p. c-7, USDA, 1969)
	288,057 ac ft/yr	
Total input:	3,410,589 ac ft/yr	

Table 6

Energy Value Calculation for Proposed Reservoir Water Management Plan

Pathway on Figure	Name of Energy Flow	A Annual Work[a] Million Kcal/Acre/Yr		B Area[b] of System, Thousands of Acres	C Region's Annual[c] Work, 10^{12} Kilocalories	D $ Equivalent for Human Work Million $ Per Region
Natural Systems West of I-95						
3	Marsh	116.5	e	40	4.66	
1	Pine flatwoods	30.9	f	88.8	2.74	
4	River	39	g	2	0.08	
5	Lakes	54.4	h	27	1.47	
2	Cypress hardwoods	51.5	i	15	0.77	
7	Improved pasture	60.3	m	131.5	7.93	
6	Intensive agriculture	38.2	l	40	1.53	
8	Urban and roads	5	j	35.5	0.18	
East of I-95						
9	NASA area	47.6	n	104	4.95	
8	Urban area	10.7	0	179	1.91	
6, 7	Agriculture	35.7	p	9	0.32	
10	Other vegetation	20.6	q	3	0.06	
	Subtotal:			674.8	26.60	2,660
Other Contributing Flows:						
11	Heat gradients on land from sun's heating	58	k	654	37.93	
12	Natural Subtotal:				64.53	
Urban Energies:						
	Bunker C fuel	3.5 x 10^4 kcal/gal[s]		8.95 x 10^8 gal/yr[r]	31.30	
	Diesel fuel	3.5 x 10^4 kcal/gal[s]		9.2 x 10^7 gal/yr[r]	3.20	
	Gasoline	3.2 x 10^2 kcal/gal[t]		4.08 x 10^8 gal/yr[r]	13.03	
	Natural gas	278 kcal/cuft[w]		34.8 x 10^9 cuft/yr[r]	9.67	
	Food	9.12 x 10^5 kcal/cap/yr[r]		958,000 people[r]	0.84	
13	Urban Subtotal:				58.04	
14	Total				122.58	12,258
15	Work done elsewhere paid for with purchases	$2,140. x 10^6				

Footnotes to Table 6

a.-d. Same as Table 3.

e.-h. Same as Table 5.

i. Cypress productivity decreased due to lowered water table – 1/2 of value of i. in Table 3: 4.37g C/m^2/day (Carter et al., 1973).

j. Same as j. in Table 5.

k. Same as k. in Table 3.

l. Agriculture productivity decreased in 1/2 of the area due to lack of irrigation water due to high urban demand 1/2 of value l. in Table 4 (Schroder and Ruelke, 1959; Schneider and Childers, 1941; Ashton, 1956). The other 1/2 of the area will be adequately irrigated and have a value equal to l. in Table 4. The resulting value for the entire area is 3.22g C/m^2/day.

m.-p. Same as Table 5.

q. Other vegetation production decreased due to lowered water table 1/2 of value q. in Table 4: 1.75 C/m^2/day (Carter et al., 1973).

r. Volume per year determined by multiplying 1970 values by 4. To determine the amount of water available with Lake Washington as a reservoir:

Using 1/3 of the average flow (1500 ac ft/day x 1/3 = 500 ac ft/day) as that available when Washington is controlled of which 100% is available for urban development, then 163 MGD is available. Then this can support 958,000 persons. At a density of 5.1 persons/acre (this includes industry and support services) a total of 187,000 acres will be developed. This means that the population is increased by a factor of 4 (958,000/230,000).

s.-u. Same as Table 4.

v. Monies increased by a factor of 4 (see r. above).

w. Same as w. in Table 4.

y. Water availability:

Total water input equals the value calculated for the primitive state minus man's diversions.

Diversions:

182,500 ac ft/yr	- urban water supply within Brevard County
144,540	-reduced input due to altered drainage patterns
44,100	-irrigation of 18,000 acres of pasture @ 29.4 inches of water (p. c-15, USDA, 1969)
340,000	-runoff from west diverted to south for irrigation in Indian River County
60,000	-irrigation of 40,000 acres of citrus @ 18 inches of water (p. c-7, USDA, 1969)
771,140 ac ft/yr	

Total input: 2,927,500 ac ft/year

Table 7

Energy Value Calculation for Floodplain Conservation and Recycle Plan

Pathway on Figure	Name of Energy Flow	A Annual Work[a] Million Kcal/Acre/Yr	B Area[b] of System, Thousands of Acres	C Region's Annual[c] Work 10^{12} Kilocalories	D $ Equivalent[d] for Human Work Million $ Per Region
Natural Systems West of I-95					
3	Marsh	242 [e]	162	39.2	
1	Pine flatwoods	41.2 [f]	94.6	3.90	
4	River	19 [g]	3	0.06	
5	Lakes	13.6 [h]	15	0.20	
2	Cypress hardwoods	103 [i]	15	1.54	
7	Improved pasture	80.4 [m]	68.2	5.48	
6	Intensive agriculture	51 [l]	20	1.02	
8	Urban and roads	10 [j]	2	0.02	
East of I-95					
9	NASA area	47.6 [n]	104	4.95	
8	Urban area	21.5 [o]	89	1.91	
6,7	Agriculture	71.5 [p]	55	3.93	
10	Other vegetation	41.2 [q]	47	1.94	
	Subtotal		674.8	64.16	6,416
Other Contributing Flows:					
11	Heat gradients on land from sun's heating	58 [k]	654	37.93	
12	Natural Subtotal:			102.09	
Urban Energies:					
	Bunker C fuel	3.5×10^4 kcal/gal[s]	4.48×10^8 gal/yr[r]	15.68	
	Diesel fuel	3.5×10^4 kcal/gal[s]	4.6×10^7 gal/yr[r]	1.60	
	Gasoline	3.2×10^4 kcal/gal[t]	2.04×10^8 gal/yr[r]	6.52	
	Natural gas	278 kcal/cuft[w]	17.4×10^9 cuft/yr[r]	4.84	
	Food	9.12×10^5 kcal/cap/yr[u]	456,400 people	0.42	
13	Urban Subtotal:			29.06	
14	Total			131.15	13,115
15	Work done elsewhere paid for with purchases	$1,070 x 10^6			

Footnotes to Table 7

a.-i. Same as Table 3.

j. Same as j. in Table 4.

k. Same as k. in Table 3.

l.-q. Same as Table 4.

r. Volume/yr increased by a factor of 2.

To determine possible population under this alternative take 1/3 of the original minimum dry season flow prior to diversion to Indian River = 362 cfs. 716 ac ft/day x 1/3 = 238 ac ft/day = 77.5 MGD @ 170 gal/person = 456,400 people ratio of 456,400/ 230,000 - population doubled @ 5.1 persons/ac = 89,500 acres into urban land uses.

s.-u. Same as Table 4.

v. Monies increased by a factor of 2 (see r. above).

w. Same as w. in Table 4.

y. Water Availability:

Total water input equals the value calculated for the primitive state minus man's diversions.

Diversions: 86,211 ac ft/yr - urban water supply within Brevard County
60,000 - irrigation of 40,000 acres of citrus @ 18 inches of water (p. c-7, USDA, 1969)
146,211 ac ft/yr

Total input: 3,552,429 ac ft/yr

Comparison of Alternatives Assuming Continued High Level of Growth

Table 8 summarizes the calculations made in the value Tables 3-7 for conditions of continued economic growth. In these calculations the floodplain conservation plan shows the highest value for the regions when fossil fuel and money are not considered limiting. The proposed reservoirs bring in high urban value but lower values in other parts of the system thus lowering the total value.

Condition Prior to Man

Under this primitive condition, Table 3 shows a high useful energy flow for the region (113×10^{12} kcal/yr). This was due primarily to the large areas of productive marshland maintained by the level gradients, runoff and the seasonally fluctuating river levels.

Present Condition in Brevard County

The total work value for Table 4 shows that the present Brevard County has a lower total energy flow than did the primitive Brevard County (Table 1). The decrease in value is primarily due to the loss of marsh (23×10^{12} kcal) which has a very high value of productivity. The urban energy (14.5×10^{12}kcal) added does not make up for this loss and there is a decline in total value.

Continued Private Development in the Floodplain

The total energy flow shows that continued private development in the county has the lowest value of any of the alternatives (Table 5). To obtain the total work values for the private agricultural alternative, the calculations were repeated but with a change in acreages that may follow if the current development continues. More marsh is

Table 8

Summary of Calculations for 5 Possible Alternatives of Development in Brevard County Assuming a Continued Rate of Growth

Alternatives	Natural Subtotal x 10^{12} kcal/yr	Urban Subtotal x 10^{12} kcal/yr	Total Useful Energy Flow x 10^{12} kcal/yr	$ Equivalent per Year Billion $
Primitive	113.39	-	113.40	11.340
Present	90.03	14.53	104.56	10.456
Private development	67.58	21.79	89.37	8.937
Proposed reservoirs	64.53	58.04	122.58	12.258
Floodplain conservation and recycle	102.09	29.06	131.15	13.115

changed to drained pasture land and more agricultural land is changed to urban usages with increasing input of fuels. However, fresh water availability in the region is limited and would probably become more limiting under this alternative (Footnote 4, Table 5). Using a ratio of 170 gallons per day per person and an available divertable supply with existing lakes and reservoirs estimated at 35.2 million gallons per day[1], the urban system was expanded from present 230,000 people to one of 343,000 people and all the urban flows were increased by 1.5. In effect, water in this calculation is moved from being an amplifier on the natural ecosystems to one on the urban system where it has larger value because of the large fuel energies added. Water is also moved to agricultural land and away from the natural ecosystems. Productivities of the natural environment decline due to the lowering of the water table (Carter et al., 1973). The water levels have already declined 2-3 feet in the floodplain and the water table follows the same gradient. Thus in these calculations urban, river, and lake values increase but natural ecosystem productivity declines.

Proposed Reservoir Plan

For the proposed water management project with several reservoirs and some marsh storages, a similar recalculation is arranged (Table 6). The proposed reservoir plan has a higher value than the 1970 condition but is lower than a well managed floodplain recycle plan. Here the estimated acreages of subsystems are recalculated using this plan which turns marsh into lake thus lowering its energy value, but augments urban values with additional water. In this calculation water is not a limiting factor and the potential permissible population is calculated from the new amounts of available[2] water and from available land. In

[1] See Footnote r in Table 5.

[2] See Footnote r in Table 6.

the low density type of housing typical of Florida, large areas of undeveloped land are used, namely all land to the east of I-95. In such cases high density affects may limit growth prior to other factors such as water.

The negative effects that an urban system has upon the natural environment are many - particularly various kinds of pollution and losses of necessary resources. To minimize these the urban system expends a large amount of energy. With increasing development these stresses become larger, affecting not only the natural environment but the urban environment as well. These represent such costs as increased sewage treatment plants, increased formal recreation costs, diminished tourist attractiveness, etc.... When the density of an urban area becomes too great increased costs make the system uncompetitive and economic growth stops, unless the high density has special amplifier effects on new energy.

Floodplain Conservation and Recycle Plan

For the floodplain recycle alternative similar calculations were made (Table 7). In this case, however, approximately 75% of the most productive marsh remains as marsh or is put back into marsh land to serve as a recycle mechanism for adjacent agriculture (both waste and water). In addition, water is no longer diverted out to Indian River except during hurricanes so that more water is available for the urban water supply downstream at Lake Washington. This alternative shows the highest total energy flow due to the high natural work flows since the marsh remains, as well as high urban values since water is also available to serve as an amplifier on urban development.

Comparison of Alternatives Considering Limits to Growth

The calculations of value for three water management alternatives cannot be made with certainty because the main sources of future energies to urban and agricultural development may be changing. Extrapolations of exponential curves is often done in Florida projections. This is surely wrong as the several external factors (energy sources) driving the recent exponential growth (see model in Fig. 12) may be leveling and show signs of leveling. Consider the main money drives that are the means for purchase of the fuel energies of urban and invensive agricultural development.

1. The first uncertainty is the declining energy resources of the United States. The costs to locate, drill and process the remaining fossil fuel and to develop nuclear power are becoming increasingly high. These costs will be borne by all consumers. To purchase fuel from abroad creates balance of payment difficulties and leads to dollar devaluation due to our less competitive energy position. The decrease in value for the dollar may affect retiree and tourist spending and the difficulties with balance of payments may affect capital funds available for investment. How Florida may fare relative to the other states is a main question.

2. Government payroll and contracts are a large part of Brevard County income. Fuel purchases are proportioned to this income. Unless Brevard County obtains another large federal project, there is little evidence that the government income will be increased or decreased much since the space shuttle program replaces the Apollo program. Industrial income in selling to government programs in Brevard County is included. Cautious extrapolations require this income be held constant. Since the cost of fuels is rising rapidly,

having doubled in cost to power plants in the last two years, the net energy income represented by the fairly constant federal appropriation must go down. Table 9 shows alternatives of constant energy and halving of energy bought from oil companies.

3. Another substantial part of the income (for purchase of energy and necessary goods and services) is from tourism and retirement and many extrapolations of value are made anticipating further increases. This tendency may be estimated as proportional to the product of the life quality image, the population of the U. S. and the dollar savings of the population that contribute to tourism and retirement. Conservative extrapolation and most recent data indicate that the U. S. population could level especially if fuel costs go up further as they have recently and as predicted as rich resources become scarce. Fuel purchases affect the balance of payments and general economic surpluses. Holding the population of the U. S. down and reducing the net earnings of that population will tend to reduce the income to Florida unless the Florida position holds a high image compared to the rest of the country.

The Florida image for attracting tourists, retirees, and other immigrants is made up in part of the quality of life indices of the coastal beaches and the inland panoramas such as those represented by the St. Johns River, marshes, wildlife, fishing, recreation, and the image contributions of high quality urban environments, human settlements, and especially job opportunities. The increasing costs of fuels may make the winter heating and clothing costs higher to the north relative to Florida, but for summer air conditioning the cost effect may be in reverse. A cautious extrapolation requires that the tourist, retirement, and other immigration rates be held constant with the strong possibility that these sources of income will diminish. In addition, those alternatives which encroach upon the green panorama converting the marshy buffer areas into more intense human developments may be expected to lower the general regional attractiveness image for tourists and retirees.

4. New capital investments in Florida are based in part on the undeveloped lands to be converted into human settlements, business activity driven by other incomes and agriculture. Much of the pressure for further draining of the St. Johns River basin comes from anticipation of attracting development capital. However, if Federal payrolls and tourist-retirement inflows stabilize or decline, the amplifier effect of the land on development may diminish especially where the land development begins to work against images and causes increases in tax levels and general costs associated with higher densities. Such costs include higher taxes, greater demand for services and reparation of declining urban buildings and roads.

5. Another growth possibility is light industry which is low in water demands, requiring high degrees of technology and with a high income return for power expended. Part of the attraction for additional industries concerns the quality of life image for its management and employees as well as levels of power. In part, this source of income depends on relative position of American technologies in world competitions. For those alternatives with quality of life image being sustained, there is a possibility of continued growth feeding in part on the Federal payroll stability.

6. Intensive agricultural production is another means by which fuel power may be amplified into sales with reasonable balance of payments to provide possible increased net incomes. However, the rising cost of fuels reduces the effectiveness of this source and

and in competition for water, the amplifier value of the water on income from outside is greater for light industry than for agriculture. The amplifier effect of water is also greater in maintaining natural areas for quality of life image to maintain tourist, retiree and new industry immigration than for agriculture. With these uncertainties, a conservative extrapolation holds the money income from agricultural sales in proportion to present lands farmed. Rising fuel costs will raise food costs world-wide and increase agricultural income for those areas that use less fossil fuel subsidy. Where Florida fits in comparative position on agriculture with high fuel costs is not clear.

With the uncertainties about the future incomes to the region, extrapolations of potential value are risky and large plans that assume particular trends are risky. One principle available for planning in a period of changing money to energy ratios is the diversity concept. Providing a diversity of land-uses may give flexibility and stability allowing whichever of water and wetlands that turn out to develop highest value. It is safer not to put all the water into one usage concept. Also a mixture of the several uses does provide a higher energy value estimation if there are limited amounts of fossil fuels that may be bought or generating incomes for Florida.

Summarized in Table 9 are energy values for future alternatives with the following extrapolations:

A. Continued high rate of growth (from Tables 5-7).

B. No further growth in fossil fuel.

C. Extrapolated fossil fuel growth continuing as in the past but the cost of the fuel doubling in price.

D. Growth in annual fossil fuel consumption increasing with only the light industrial growth continuing at the same rate and with a leveling of tourists, retirees, agricultural, and government payrolls.

E. Fossil fuel imports remain constant and the cost of the fuel doubles.

Table 9

Comparison of Annual Energy Values for Water Management Alternatives Under Contingencies of Energy and Economies that May Affect Growth in Brevard County (x 10^{12} kcal/region/yr)

	Present 1970	Private Development	Proposed Reservoirs	Floodplain Conservation Plan
Continued high rate[a] of growth	104.5	90.20	124.11	131.41
Fossil fuel [b] held constant	-	82.11	79.06	116.62
Energy cost [c] increased by 2	97.3	78.49	93.55	116.62
Fossil fuel held [e] constant but also energy cost increase by 2	97.29	74.85	71.80	109.36
Exponential growth of [d] diverse light industry with constant agriculture, tourists, and federal payroll (assumed to be 31% of budget)	-	82.62	104.58	122.14

Footnotes to Table 9

a. Growth continues at a very high rate, increasing federal payroll as well as increasing industry, agriculture, and tourism. Taken from total values in Tables 3-7.

b. Fossil fuel held constant with no additional energy for county but the natural values continue to be diverted to developed uses. Natural value obtained from Tables 3-7. Urban values taken from Table 4 for 1970 conditions.

c. The cost of energy doubles (or 1/2 of energy diverted) due to increased costs, but natural areas continue to be developed. Here the fossil fuel increases but since it costs more less work is done. Fossil fuel values taken as 1/2 of urban energy value in Tables 5-7. Natural values continue to be diverted.

d. Growth is taken to be exponential for diverse light industries but is held constant for 31% of the current budget. This 31% makes up tourists, Federal payroll, and agricultural budget which may not increase at same rate as industry, particularly with the loss of image in the region. Natural values continue to be diverted to developed areas (Tables 5-7). Urban values taken from Tables 5-7 but 31% of budget held constant while rest permit to grow.

e. Fossil fuel coming into the county held constant at 1970 values. However, cost of the obtaining of this fuel doubles.

Simulation of a Simplified Model to Determine the Optimum Level of Development in Brevard County

In all of the previous tables the values were calculated by hand from land use maps, current economic data, and economic assumptions of growth. In this section the model of the county (Figure 14) was simplified so that no land use maps and detailed evaluation of vegetative productivity was used. Macromodels which show postulated overall relationships may be as accurate as detailed evaluations that may miss such overall interactions as they tend to develop beyond our experience.

Here current economic data from Brevard County (1970) and current level of development were used in computer simulations to predict the optimum level of development in the county. Thus differences in these computer simulations and the results of the previous tables are due mainly to the increased loss of natural energy as development proceeds. As development proceeds, value is automatically decreased in the natural environment. In the previous tables the only stress that was determined was change in productivity of the natural environment. In marshes this is frequently decreased by development and in lakes it is frequently increased. In the simulation the stress may be more realistic in that as developed energy increases, an increasing proportion of natural energy is lost due to the square term in the model (this follows the second law of thermodynamics for as more energy is expended a greater proportion of it goes into heat).

A simplified version of the Figure 14 was simulated to determine the optimum level of development in Brevard County (from Odum and Odum, 1972, and Odum, Littlejohn, and Huber, 1972). In this model (Figure 16) all natural energies are combined and interact with natural land to produce natural structure (called value image). This is the structure that makes up the natural environment: lakes, river channels, marsh communities, cypress swamps, dune structure and vegetation, beaches, soil and microclimate. Developed image or structure is made from man's activities. With fossil fuels and some contribution from the natural structure land is converted from native land to developed land. As the amount of development increases, the damage or stress that this inflicts upon the natural image increases. The sum of the natural structure and developed structure is the total structure. In this model also energy flow or work is the value that is considered. Economic flows are converted to energy flow for the model (details are given in Bayley et. al., 1973).

In this simulation the county was divided in two simulations - west of Interstate-95 and east of I-95. The model output from the two halves of the county were then added to give the total value for each water management alternative. Figure 17 presents results of the value model for Brevard County west of I-95. This is the floodplain and agricultural region. As development increases converting land from natural uses to developed uses (agriculture), the total value declines. Even with an exponential increase in fossil fuel energy, total values decline. In the model simulation for the drier coastal region (Figure 18) as development increases beyond 50% of the region east of I-95 is developed, the total value declines due to the loss of the free natural subsidies. This model assumes that an exponential increase in fossil fuel will be available to provide energy for further development and maintenance of existing development. Figure 19 plots development vs. total value for a linear increase in fossil fuel. Starting with the current conditions (% developed east of I-95), with linearly increasing fossil fuel the optimum total value occurs at 40% development. This implies that a region must continue to receive an exponential increase in fossil fuel or the value will decline. In the floodplain even with the addition of fossil fuels the total value declines. This may be due to the extremely high work or energy flows within the marsh.

The five alternative water management programs each provide for a particular level of development, when this percent development is plotted in Figure 17 and Figure 18 the amount of work or value can be plotted. Table 10 shows the total value for each alternative east and west of I-95. The sum of these gives the total energy flow or value for each of these alternatives in Brevard County. Thus, both the continued private development and the proposed reservoirs lower the total value of the county. Only the floodplain recycling alternative increases the total value of the county. In the calculations of tables based on pathways in Fig. 12 image was acknowledged, but not incorporated in any objective way by changing the forcing functions except that calculations were made with different amounts of fossil fuel, which are proportional to the incomes generated by the region's activities. The simulation in Fig. 16 was done with the image being the product of several kinds of work generating value (natural work and urban work). Even holding the fossil fuel availabilities constant (same as holding price constant), the image effect produces a maximum value at less than full development as was found in a similar calculation for Naples, Florida. If this model has the correct kind of interactions of the real natural and fossil fuel work processes, it suggests economic viability requires a better balance and variety of land uses than full development even if the fuel sources were not declining and becoming more costly. A safe and sane plan for the long run requires management for mixed areas of marshes, agriculture, and urban development.

Value Model of Brevard County
at initial conditions (1970)

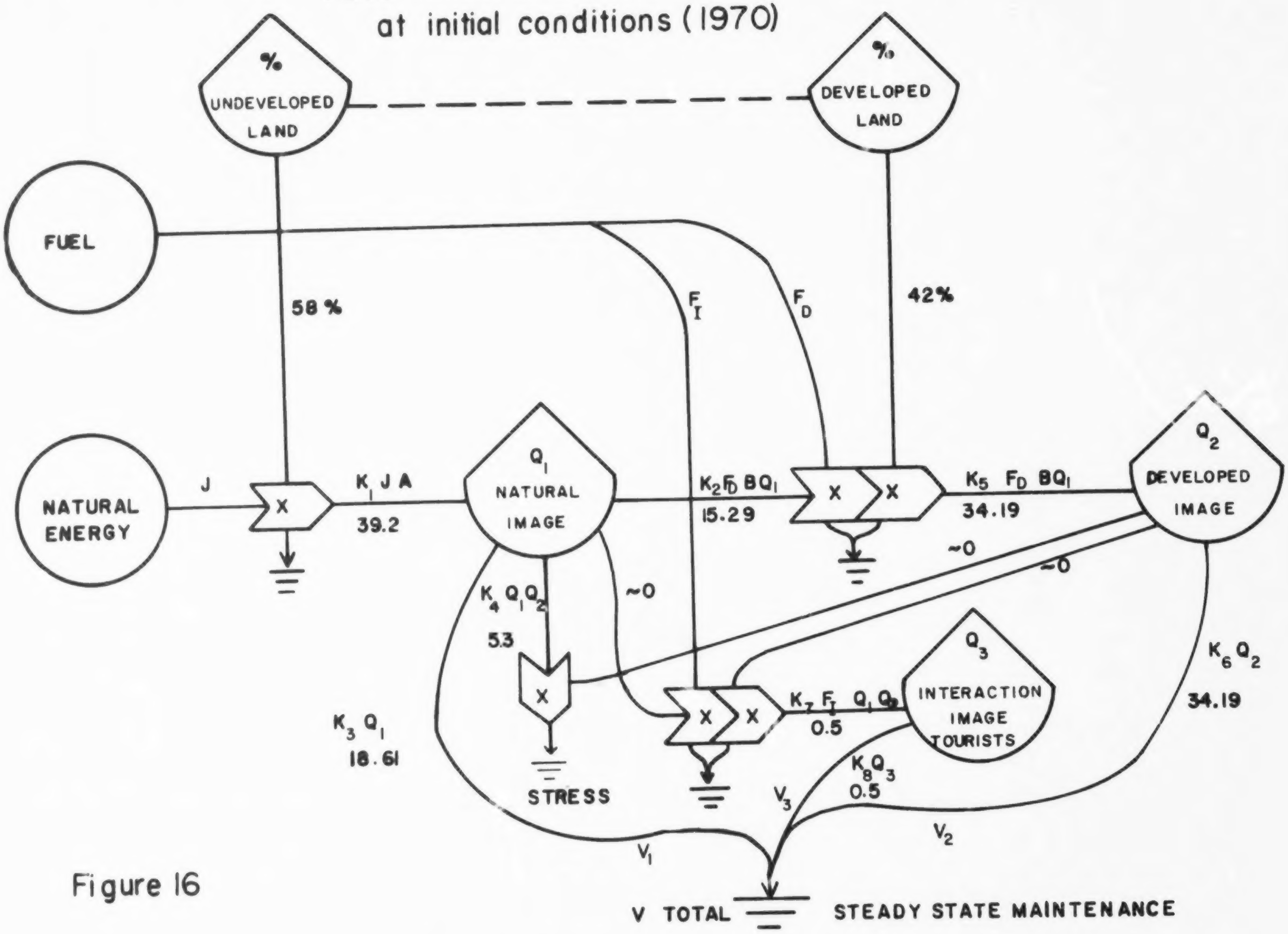


Figure 16

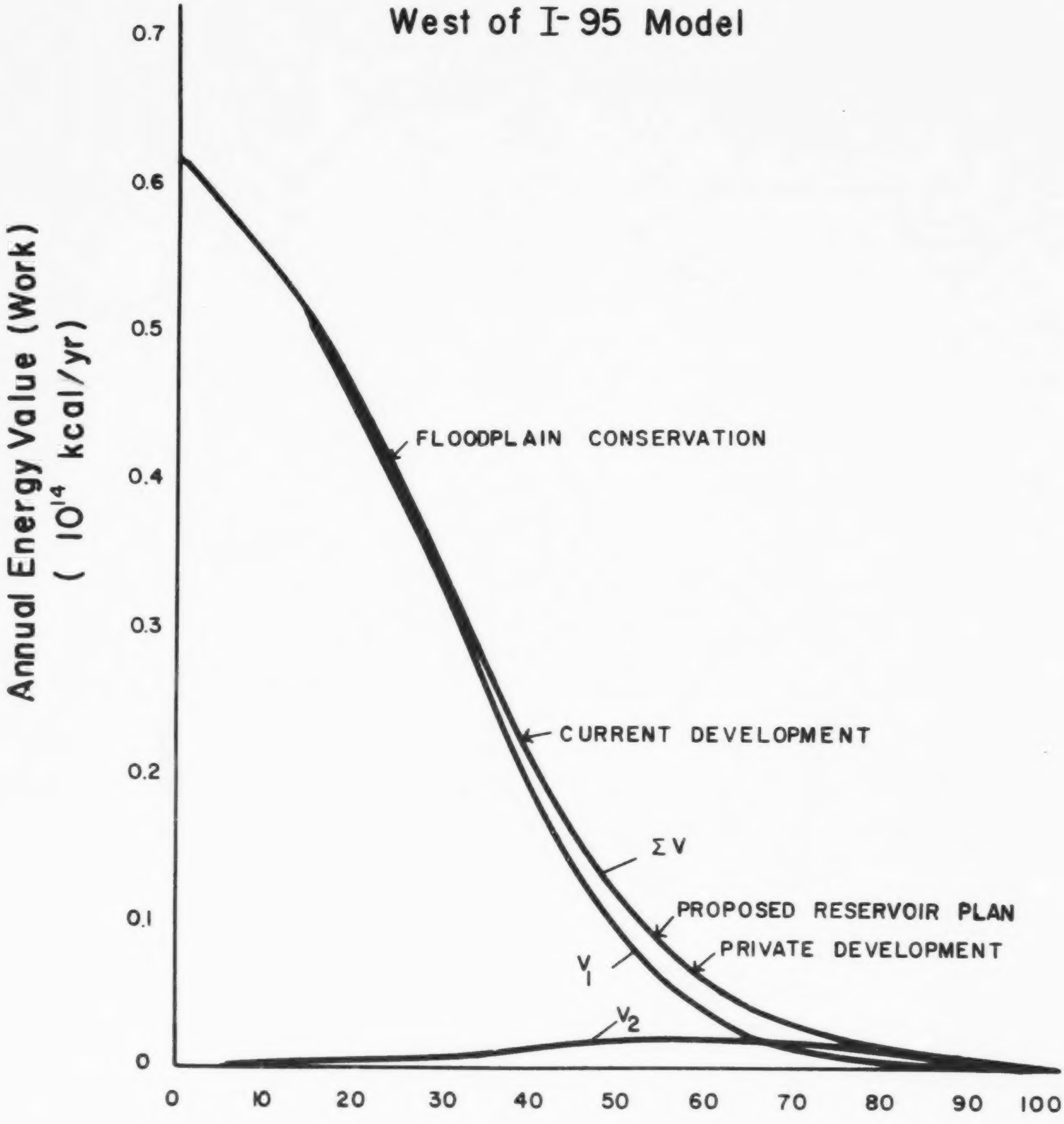

West of I-95 Model
Annual Energy Value (Work)
(10^{14} kcal/yr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
FLOODPLAIN CONSERVATION
CURRENT DEVELOPMENT
ΣV
PROPOSED RESERVOIR PLAN
PRIVATE DEVELOPMENT
V_1
V_2
0
10
20
30
40
50
60
70
80
90
100
PERCENT DEVELOPMENT

FIGURE 17

East of I-95 Model

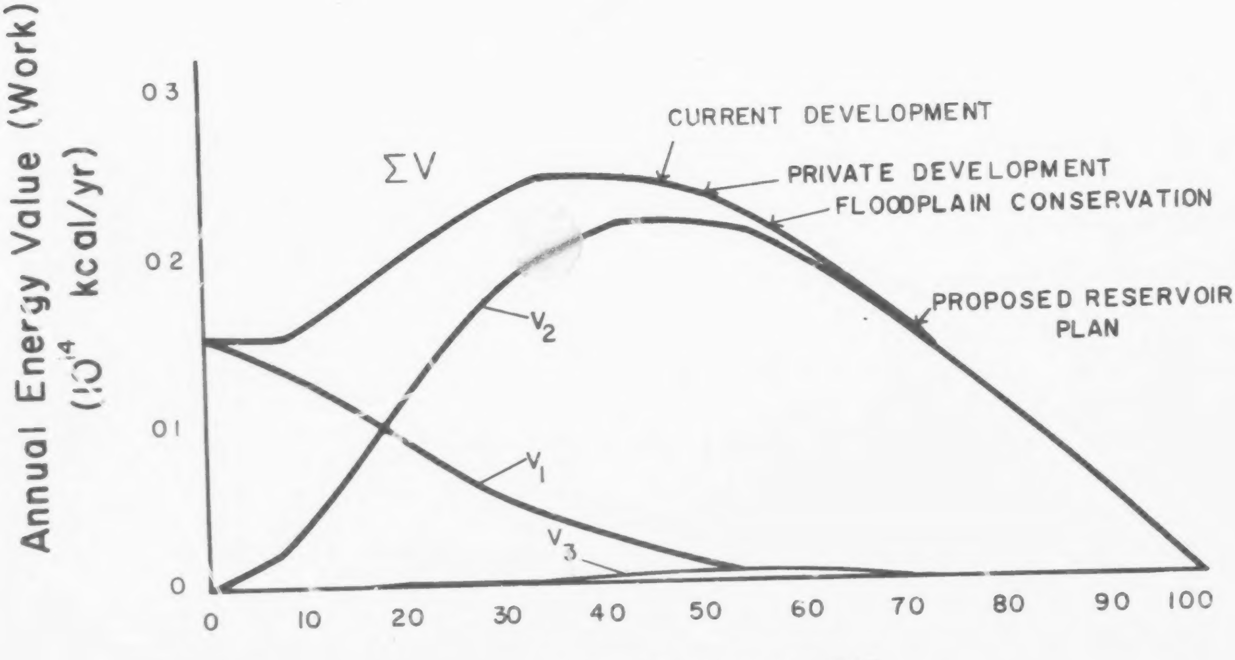


FIGURE 18

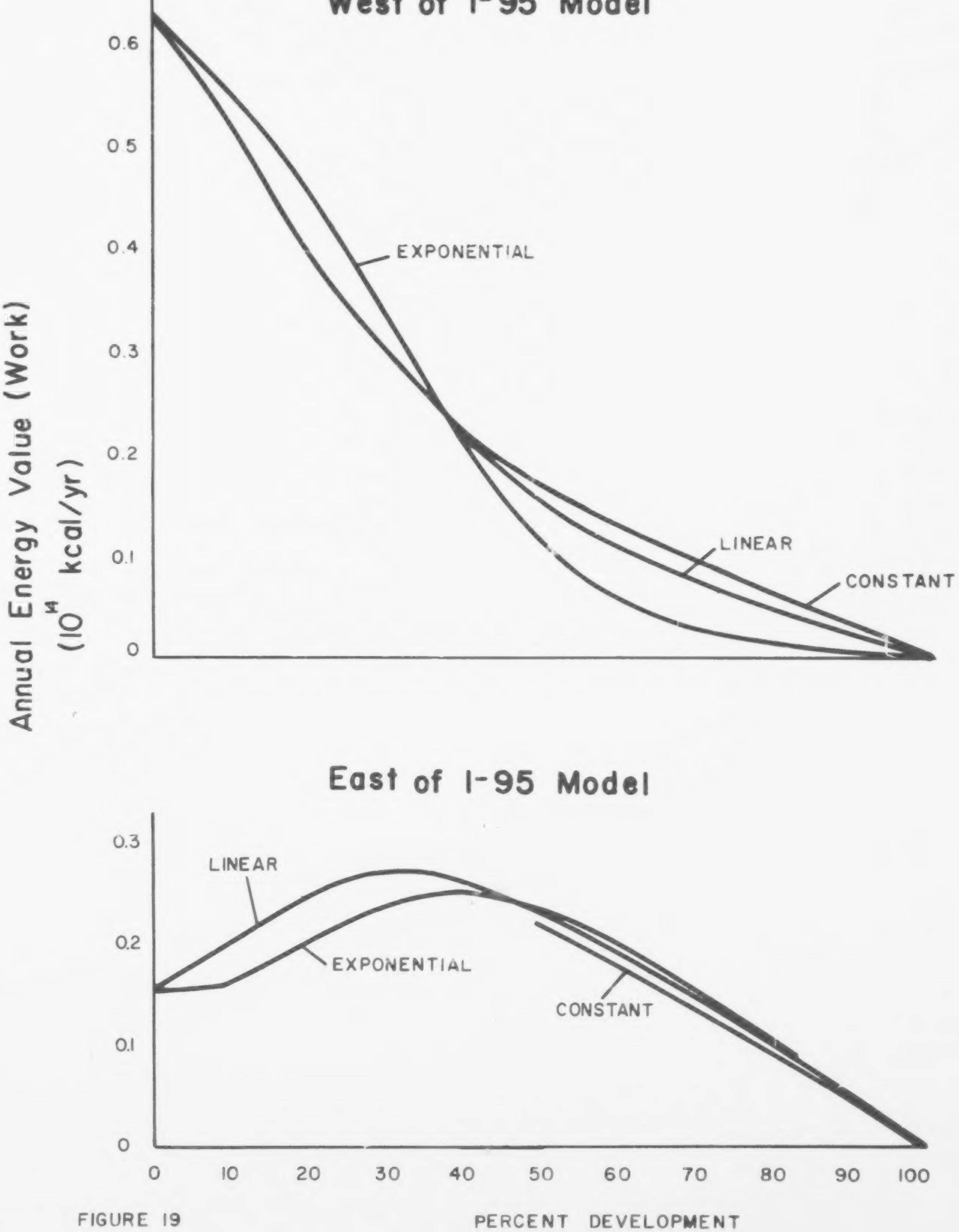

West of I-95 Model
0.6
0.5
0.4
0.3
0.2
0.1
0
EXPONENTIAL
LINEAR
CONSTANT
Annual Energy Value (Work)
(10^{14} kcal/yr)
East of I-95 Model
0.3
0.2
0.1
0
LINEAR
EXPONENTIAL
CONSTANT
0
10
20
30
40
50
60
70
80
90
100
PERCENT DEVELOPMENT

FIGURE 19

Table 10

Total work* for each alternative from Total Value Graphs for East and West of Interate 95 in Brevard County

(x 10^{12} kcal/yr or x 10^{8} \$/yr)

	Current Development x 10^{12} kcal/yr	Private Development	Proposed Reservoirs	Floodplain Recycling
West of I-95	22.2	6.6	8.8	41.2
East of I-95	24.2	23.5	15.2	21.5
Sum	46.6	30.1	24.0	62.7

*Annual Energy Value

DISCUSSIONS OF THE MAIN COMPONENTS OF VALUE

The alternatives presented in this report represent to some extent the range of possible development in Brevard County. The decision to build the proposed reservoirs or to permit extensive floodplain agriculture or to follow some plan of floodplain conservation is in essence to choose the type and level of growth for the region for some years to come.

Effect of Water Decision Alternatives

There are several assumptions which are very important in the consideration of the alternatives for future development. In all three plans, the private development, proposed reservoirs, and floodplain conservation, we first assumed that the region will maintain its ability to draw in outside money and services at the same rate that the county has thus far (Table 8). The models also assume that fossil fuel for development will be available at the same rate that it has thus far. If these assumptions are not met (shown in Table 9) then a decrease in the natural component of the total system is of even greater importance. Image or attractiveness to the value of the region for continued development is an important indicator to be discussed later.

While not including man, the primitive alternative had very high natural productivities due to the interaction of water, river, lakes and marsh. In this system the marsh utilized the nutrients building up large biomass of peat within the marsh, leaving the river and lakes with little net accumulation of sediment. The fresh water character of the surface waters was maintained by the ample runoff and river flow.

Under present conditions much of the natural land has been converted to agricultural use in the floodplain and to urban use on the higher elevations. Although there has been a loss of the natural productivity of the region, the added urban values such as NASA, industries, and tourists have brought the total value of the region partially back to previous productivity. However, as demonstrated in Tables 3-9, the extensive use of the floodplain has not brought the region a proportionate increase in energy or money (Table 11). In 1970, economic contributions of agriculture to Brevard County were less than 1% of the total economic budget. This economic benefit did not offset the loss of extensive marshland production and there was a general decline in total energy flow.

Among the problems currently facing Brevard County due to its management practices in the floodplain, are the decreased water availability for both natural and urban systems, decreased wildlife value and decreased productivity of fish in the agricultural parts of the river (Cox and Auth, 1972).

Increased nutrients and sediment accumulation also are raising problems to be discussed later. During periods of low flow the river increases in salinity primarily due to free flowing wells from the saline Floridian aquifer which are used mainly for irrigation (Brown, et al., 1962.).

As part of this study unit water budgets were made to determine whether a generalized natural marsh or an agricultural system with reservoirs would conserve the most water (Bayley, et al., 1973). These calculations indicated that an agricultural system with reservoirs lost 122,000 ac ft/yr (108 MGD) more water than did the same area in marsh. These calculations were made using data from 1970 conditions in the marsh between State Road 192 and 520. This indicates that agriculture and reservoirs tend to lose water rather than conserve it and the value that one obtains from such systems should be examined.

The purpose of the proposed reservoir plan is to provide irrigation water to certain areas, to control flooding in the floodplain and to provide some urgan and recreational benefits (U. S. Army Corps of Engineers, G. D. M., 1957 & 1962). Data presented in Bayley et.al. cast doubt on whether all of these benefits can be provided. The Corps indicates that they will supply 500,000 acres with irrigation water. If they attempt to supply a minimum of 6 inches of water per year then 250,000 acre ft/yr are required. Transmissions losses are usually 25-30% of the total (USDA, 1969), so 75,000 acre feet more must be provided (total of 325,000 ac ft/yr). From the unit water models in Bayley and Horsley (1973) (or 1 cfs/sq. mile for the western watershed) the western slope will provide approximately 340,000 ac ft/yr. If the FCD tried to provide all the agricultural benefits claimed, 15,000 ac ft/yr would be going down the Jane Green Creek to join the St. Johns rivers for urban use and to provide continued flow downstream. The rest of the 340,000 ac ft/yr would be diverted south for use primarily in Indian River County and most will be lost to Brevard County. Melbourne currently uses 10,000 ac ft/yr for urban water supply. This allows little additional water for increased water demand or to provide a minimum flow for the river. These are only average flows and a reservoir can store water (380,000 acre ft) but there is greater loss through evaporation and the greatest demand for both irrigation and urban uses comes during the dry season in drought years. We do not know which uses (urban or agricultural) will have priority.

In the calculations made in this report the proposed reservoir alternative gives very high work value due to the high urban benefits derived from the available water and space. This is one of several possible results for the proposed reservoir plan. If the federal payroll does not continue to provide increasing economic assistance then the county might tend toward a more industrial or tourist based economy. This would affect the use of water and the total energy flow. The urban energy (and dollars) comes to Brevard County in response to land availability, availability of ample fossil or nuclear power for development and the image of the area as well as numerous other factors. Thus the calculations made in Tables 3-7 may be the maximum development for the area. If fossil fuel becomes limiting or the cost of energy increases then the values presented in Table 8 would be generous and the total value of the region would be less.

If neither the proposed reservoirs nor a floodplain conservation plan are instituted then the region will continue to grow in a manner similar to the present development until factors such as water, space, fossil fuel become limiting. In this report the calculations consider water or space to be the main limiting factors on further development due to current land use projection plans and diversion of water outside the basin. Other possible calculations can be made if the fossil fuel sources decline, and if the image or competitive advantage were to decrease. This would surely occur if water were limiting or if the federal assistance did not continue to increase. Thus the calculation of urban energy made for this alternative may be high. In this alternative problems already experienced would probably increase; particularly low ground water levels, increased salinity of fresh waters, eutrophication and sedimentation of the lakes and rivers, and limited water available for municipal water supplies.

The High Stress Energy Costs of High Density

Intensive agriculture and especially urban developments may develop high concentration of work per area, thus concentrating functions such as noise, high density deterioration, waste water and air processing, and energy losing human interactions such as crime. In the models these negative processes are an inherent part of the higher energy systems requiring part of the fuel energies to be diverted from value generating work into extra expensive maintenance costs. Police forces, special sewage plants, solid waste works, special recreational costs, more regulatory costs, etc. are part of high energy systems. Because of these the high density system may not compete as well economically in times of non-growth. With less dense areas there are better blends of natural areas and urban life with more economic yields. Currently the power density of the urban area is 35 kcal/m^2. A high density area such as New York City has approximately 4000 kcal/m^2.

Thus any extrapolation of growth must include higher tax rates and costs, with less fossil fuel being available for net value over and above the special costs created by its own growth.

The amplifier value of water in facilitating fossil fuel based on agricultural or urban developments is high at first, becoming less and less as the density of that development develops its own internal stress costs and diversions so that it does not develop the balance of payments necessary to compete at any further density. This effect is the stress multiplier and the square terms in Figures 12 and 16.

Energy Role of Nutrients

Nutrients within ecosystems recycle but additions of nutrients crossing into the system from outside are an energy source and forcing function. Urban and agricultural developments have these special energy sources that affect productivities and net gains of organic matter in sediment and peat. Nutrients exported as floating organic matter in rivers or high nutrients in waters affecting water quality users downstream are results of this added energy source. Whereas reservoirs become eutrophic and tend to fill with hyacinths and sediments, wetlands with fluctuating hydroperiods tend to spread out such nutrients causing a general and less concentrated deposition which may reach permanent outlets through timber growth, ground water recharge, or harvests in pasture, wildlife, etc.

The energy value of nutrients to the system for good or for bad is the energy stimulation to growth processes. The energy value of wetlands to a water using system where water quality is important is the work of nutrient amelioration which would otherwise have to be done by technological means. This costs the region or society money, affecting its balance of payments, and ability to stimulate incomes. The models include nutrients in the developed alternatives and the diverted fossil fuels associated with the nutrients are a part of the life support values to development that are lost when development becomes dense.

Sensitivity to Nutrients

In the models, changes in the nutrient concentrations are not considered directly (see Bayley and Horsley, 1973), but are important due to the interactions and influence they have on the entire system.

The most important interaction affecting the management decision is the relationship between nutrients, water hyacinths or other plant growth and sediment accumulation. In the primitive situation, the river had a balance between nutrient availability, plant growth, decomposition and the flushing action of the river which maintained a balanced sediment level with little net accumulation.

In the current situation the nutrient concentrations have increased and are currently increasing (Bayley and Horsley, 1973) and lead to the growth of water hyacinths in the river and algae blooms in the lakes (particularly Blue Cypress Lake, Goolsby et. al., 1970). After the seasonal growth these plants die, fall to the bottom and add to the sediment layer. Although natural decomposition occurs, the system is not yet adapted to handle increased sediment loads, the the sediment accumulates. Attempts to control the water hyacinths by spraying lead to increased sediment deposition (Timmer and Weldon, 1967) and return more nutrients to the river to further aggravate the problem. Decomposition of organic matter or the introduction of ground water with low dissolved oxygen leads to low dissolved oxygen in the river during the summer months (Bayley and Horsley, 1973). Low dissolved oxygen in water is harmful to fish (Warren, 1970).

Sediment has been accumulating in the lakes in that part of the drainage most influenced by agricultural runoff - Lake Helen Blazes, Sawgrass and Washington (Cox and Auth, 1972). In Lake Helen Blazes, the most influenced by agriculture canals, in the last 15 years there has been a net accumulation of approximately two feet of sediment. This includes at least 2 periods of drawdown when the lake was almost completely dry and the sediment able to concentrate and be reduced by oxidation. The increase in sediment reduces the ability of the lake to store water and the water leaves the lake faster and may increase flooding elsewhere.

There are several methods for removal of sediment from lakes in Florida. These include draining and drawdown of the lake to concentrate and reduce the sediment (report on Lake Tohopekaliga; Wegner and Holcomb, 1972) and dredging of the lake sediment with dragline or other equipment (Wilbur, 1972). It is still debatable whether drawdown of the lake is an effective way to control sediment accumulation since the factors which caused the accumulation are frequently still in operation, particularly increased nutrient addition and stabilization of the lake levels.

Under both alternatives, the proposed reservoir and the continued private development in the floodplain, sedimentation must be considered. In the evaluations used in this model, the sedimentation rate was assumed to be the same as that in Lake Helen Blazes and applied to the entire lake or reservoir system in the valley. Assuming current rates, the proposed Lake Washington Reservoir would fill in 25-35 years. This does not include any increases in the nutrient load which may make the rate of sedimentation faster. Under the proposed reservoir plan, much of the marsh is made into a lake, thus reducing its ability to oxidize sediments. The cost then of managing the natural sediment cycle as well as those caused by the increased nutrients must be borne by man. This includes the cost of dredging or draining (which may be difficult in an urban water supply), and must also include the cost of the land that is used to receive the lake sediment. This probably will be increasingly expensive as the land is developed. For this man is paying twice, first to build a water control structure and secondly to manage it when a marsh provides both services free. If all costs are considered, it may take up to twice as much land for man to operate a reservoir system than for the natural system to operate a similar water control system.

The Effect of Hydroperiod

In the marsh, the seasonal rise and fall of the water level which alternately covers and exposes the marsh is called hydroperiod. This is important for many functions, but particularly the productivity of the marsh and the maintenance and control of flooding. Most of the productivity and diversity of the marsh derives from ample available water and this seasonal fluctuation of water level (Bayley and Horsley, 1973). The role of marsh in storing water and slowing floods is similarly based on allowing water levels to fluctuate.

In the present and future alternatives evaluated here, the hydroperiod is curtailed or influenced by the activities of man. Currently water levels have been lowered in the floodplain (Bayley and Horsley, 1973), although the seasonal fluctuation has increased (Cox and Auth, 1972). The loss of the water has been primarily due to diversion of the water to Indian River and to a decrease in rainfall (Bayley and Horsley, 1973). The water flows have diminished from an average 813 cfs in the 1940's to 603 (1961-70), a loss of approximately 200 cfs. Rainfall patterns may also be influenced by changes in land use. A study of the rainfall patterns in Florida shows increased rain over more densely populated areas and decreased rain over agricultural and natural areas (Hamrick, 1971). This may be due to changing land use patterns with increased paving and building in urban areas and decreased water available for evaporation in agricultural and natural areas. The hydroperiod has also been changed such that the natural rise and fall of water levels is accelerated by channelization and

and reduction of the floodplain. There are larger flows in the rainy season and lower flows during the dry season than in previous decades (Bayley and Horsley, 1973). This exaggerates the problem of flooding downstream since the water flows off faster and cannot spread out over the floodplain.

Considerable discussion has taken place over the low weir currently holding water in Lake Washington. This weir which is placed at 13.5 ft. msl holds water back only during periods of low flow or low water levels. Suggestions have been made for removing this weir and for replacing it with a large structure as part of the proposed reservoir plan. Suggestions have also been made to release the water from the proposed reservoir between 16' and 17.5' msl. This is less than the 3-4' fluctuation of the water levels currently in operation in the floodplain (Bayley and Horsley, 1973) and so would reduce the hydroperiod. The turnover time or time that it takes for all of the water to be flushed out of Lake Washington is approximately 10 days. Any changes in the lake such as increasing the size under the proposed reservoir plan will increase the time the water remains in the lake. If the flow into the lake also decreases as is suggested by the data and model in Bayley and Horsley (1973), the turnover time could increase by a factor of 4 or 5. This would change the character of the lake and have important negative effects on the uptake and fate of nutrients and on sediment deposition. The increase in nutrients and the change from a lake with a short turnover time to a long turnover time favors the growth of algae and water hyacinths. [Preliminary results in Lake Alice at University of Florida show that when the flushing action ceased, the chlorophyll content of the water increased by a factor of 7 - that is, more algae were able to grow in the lake since they were not flushed out (Brezonik et. al. 1973)].

With increased plant growth and increased deposition of plant remains, the surface of the sediment in the lake becomes anaerobic and the sediment accumulates at a faster rate.

With continued private agricultural development in the floodplain, the water levels will be decreased further and the water runoff patterns exaggerated by the increased channelization. Flooding would also be a problem under this alternative.

Under the floodplain conservation plan, with no diversion to Indian River and no artificial channels within the floodplain, the hydroperiod should return to more natural levels and frequency of fluctuations. With floodplain areas available, the water is stored on the marsh naturally controlling most floods. A low weir could continue to be maintained at Lake Washington to provide for the urban water supply during periods of low flow.

Sensitivity to Agriculture, Urban or Marshland Uses

The change in land use from natural ecosystems to agricultural or urban uses is increasing rapidly in the St. Johns River basin. The original natural systems in much of the river basin were adapted to live with seasonally fluctuating water levels, and standing water during part of the year. The need for dry agricultural land has reduced the amount of land remaining in its natural condition and lowered the water levels in those areas that remain. Thus there is competition for the remaining water between agricultural and urban users and between economic use and natural vegetation. There is now a choice to make between these competing water users which may be settled by determining which users yield the most benefit to the entire region. Table 11 is a summary taken from Tables 3-7 of the natural and agricultural energies found in the floodplain, west of

I-95. When these natural and agricultural flows are viewed alone without urban development, an interesting pattern is suggested. As the floodplain developed from the pre-agriculture days to the present, the total natural energies decreased. With further development or with the proposed reservoirs the value declined dramatically. This suggests that as agriculture in the floodplain is increasing it is becoming increasingly less beneficial to the region as a whole. There is a similar effect in an urban environment where the higher tax costs with increasing density of urban development are associated with greater social costs at higher densities.

The models are highly sensitive to changes in water use from marsh to agriculture. Due to the highly productive nature of marshes, loss of this resource to agricultural uses lowers the value in the whole region. Loss of the marsh to dense urban uses may not lower the total value as much because both are highly productive systems, but when land on higher elevations (less productive) is available, the optimal planning insures that both the natural marsh system and the urban system remain separate and so contribute value to the region. The floodplain conservation and recycle plan is essentially a plan to maximize the productivity of both urban and natural regions.

Table 11

Annual Energy Value of Land Uses Under Various Plans (West of I-95)

System	Primitive		Present		Private Development		Proposed Reservoirs		Floodplain Conservation	
	10^3 Acres	10^{12} kcal/yr	10^3 Acres	10^{12} kcal/yr	10^3 Acres	10^{12} kcal/yr	10^3 Acres	10^{12} kcal/yr	10^3 Acres	10^{12} kcal/yr
Natural Ecosystems	379.8	60.34	233.0	27.06	155.5	7.96	172.8	9.72	289.6	44.9
Agricultural Systems	-	-	144.8	11.05	220.3	11.89	171.5	9.46	88.2	6.5
Sum of Natural and Agricultural Systems = Total Photosynthetic Value	379.8	60.34	377.8	38.11	375.8	19.85	344.3	19.18	377.8	51.4
Ratio of Energy to Land (x 10^6 kcal/acre/yr	159.		100.		53.		56.		136.	

Extrapolation of Conclusions Beyond Brevard County

The models and calculations were made for Brevard County but some recommendations concerning a larger area of the upper St. Johns River can be made by extrapolating energy values per acre and per acre foot of water for the various types of land use combinations. Other counties may be similar to those in Brevard County in land use and productivity per unit of land. Values may be maximized in the larger region if lands and waters are used in the same proportions to those estimated to maximize values in Brevard County. Calculations from Brevard County to aid this process are given in Tables 11-14.

The Energy Release Value of Water in Facilitating Natural Agricultural, Urban, and Industrial Work

Any material flow such as water has two energy values, one its energy value as a fuel, the other is its value in facilitating processes when it interacts with fuels. Water has some energy value as a fuel when it is elevated in mountains and used as water power. It also has some chemical value as when fresh water mixes with sea water or is used in chemical industries. Usually, however, the fuel energy in water alone is small compared to the energy value it can release in complex work as when it is used in agriculture, natural ecosystems, or urban activities. The relative energy release value of a gallon of water depends on the nature of the whole system it is stimulating. For example, an urban system which is receiving large money incomes in excess of costs may purchase additional fuel energies providing water is supplied as needed. In recent Florida history, incomes have been large from tourism, federal payrolls, retirees, and other investments so that there was a large energy to be developed per gallon of water used.

If, however, a similar-appearing urban system does not have a favorable income balance and is competing poorly in ability to draw the funds to purchase energies, then water is no longer a limiting factor and adding water has little effect, then the energy amplifier value of water may be much smaller in that system. In intermediate cases, the energy increase associated with adding more water may be partially offset by increasing energy diversions and losses due to crowding, loss of green space contributions, etc.

By evaluating the ratio of energy to water and energy to land for various conditions in the Brevard County example, some quantitative perspective is given to the value of water as a controller of energy values. Water release action was diagrammed in the small model in Figure 11a.

In Brevard County, water for agricultural or urban uses has been considered limiting and the proposed plans are to provide more water for these purposes. In Table 12 are the values of water as it releases or permits work (natural, agricultural and urban) in Brevard County (Table 12). These calculations are a ratio between the energy flow in a particular system and the amount of water in that system permitting that flow. In this table the amplifier action of water in the natural and agricultural systems is of particular importance. The amount of natural energy obtained per unit of water has decreased since primitive times (column A). It declines further with further development except under the floodplain conservation plan. The efficiency of agricultural energy (both photosynthetic and fossil fuel additions) per unit of water decreases under each of the proposed alternatives (column B). In other words, the amount of work received for each acre foot of water declines in any future alternative.

Agricultural use of water permits more energy flow (including energies in economic expansion) than does the natural ecosystem under current conditions. Under both the private development and proposed reservoir alternatives this declines and the region would receive much less energy per acre foot of water (approximately 6 x 10^6 kcal/ac ft). The floodplain conservation plan gives the highest combination of natural and agricultural energy per acre foot of water.

The energy made available by the municipal water supply is shown in column C. Here the urban energy obtained per unit of water under current conditions is the highest of any of the alternatives.

The total energy in Brevard County including natural, agricultural, and urban energy is shown in Table 13. The current total use of water in Brevard County shows a decreased efficiency of energy flow over the primitive condition. Since one cannot predict the economic base of the urban system among several future alternatives, the numbers in this table are given for several possible types of economic development. If the region were able to grow as it had in the past with no increase in oil and natural gas costs, with proportional increases in federal spending, etc., and no negative effects of crowding on images and net incomes, then the region might get the most energy per foot of water from the proposed reservoir alternative, with the floodplain conservation plan only slightly less efficient. However, it is much more likely that fuel costs will increase and facility crowding will diminish incomes, reducing the fossil fuel energies available. With this possibility, the floodplain conservation plan might provide more energy per acre foot of available water.

To compare several possible uses of water in Brevard County, Table 14 indicates the energy return for an acre foot of water.

The first 3 uses compare the amount of energy return for each acre foot of water for a natural, agricultural or urban system. The present class of urban system gives the highest return, agriculture the lowest.

To compare the productivity of a highly productive agricultural system with a productive natural environment one can compare the present agricultural value (16.2×10^6 kcal/ac/ft) with the primitive natural value (20.2×10^6 kcal/ac/ft). This may give an indication of the tradeoff which one will have for other areas of the river basin particularly Indian River County under the proposed reservoir plan. In addition to lowering both natural and agricultural values for this alternative, one may lower the natural value in Indian River County without substituting an equally productive system.

Although an intermediate density urban economy gives the highest benefit, there are several kinds of economies in Florida. Agriculturally based economy was the predominant older type with tourism now more prevalent as the economic base. Brevard County has tourism but more important has been the federal subsidy to the region. Table 15 compares the energy efficiency of an acre foot of municipal water for a tourist economy and for Brevard County. Clearly the federally subsidized economy brings more benefits per unit of water provided by the city.

If development in Brevard County is to proceed with emphasis on retirement living and investment, the gains may be less than expected for the county. Retirement communities and tourism use a large amount of water without bringing in large capitol. Light industrialization and federal subsidy may result in a more productive system.

Table 12

Kilocalorie Value of Water as an Amplifier to Isolated Energy Processes in Brevard County (10^6 kcal/acre ft)

	Photosynthetic Natural Energy to Total Water	Agricultural Energy to Agricultural Water*	Urban Energy to Urban Water*
Primitive	20.4 b		
Present	14.9 c	16.2 g	466 k
Private Development	8.7 d	10.6 h	360 l
Proposed Reservoirs	9.0 e	11.3 i	320 m
Floodplain Conservation	18.0 f	15.4 j	337 n

*When fuel costs are cheap (1970) and incomes are expanding.

Footnotes to Table 12

a. Amplifier value of water shown as the ratio of energy processed per acre foot of water.

b. The value was obtained by dividing the natural photosynthetic work of 75.45×10^{12} kcal/yr (Table 3) in the primitive state by the total surface water of 3.7×10^{6} ac ft/yr (Footnote y in Table 3).

c. The value was obtained by dividing the natural photosynthetic work of 52.1×10^{12} kcal/yr (Table 4) in the present state by the total water of 3.49×10^{6} ac ft/yr. This is equal to the sum of the surface waters and the municipal water (Footnote in Table 4).

d. The value was obtained by dividing the natural photosynthetic work of 29.65×10^{12} kcal/yr (Table 5) in the private development alternative by the total water of 3.41×10^{6} ac ft/yr. This was obtained as the difference between the total surface waters and the water lost in development (Footnote y in Table 5).

e. The value was obtained by dividing the natural photosynthetic work of 26.6×10^{12} kcal/yr (Table 6) in the proposed reservoir alternative by the total water of 2.91×10^{6} ac ft/yr (Footnote y in Table 6).

f. The value was obtained by dividing the natural photosynthetic work of 64.16×10^{12} kcal/yr (Table 7) in the floodplain conservation alternative by the total water of 3.55×10^{6} ac ft/yr (Footnote y in Table 7).

g. The value was obtained by dividing the total agricultural energies plus fossil fuel in agriculture (Table 4) by the total agricultural water. This was estimated to be negligible. This was obtained by calculating 53 inches of rain per year on the total agricultural land (211.8×10^3 acres, Table 4) plus the irrigation water of 47,000 ac ft/yr.

h. The value was obtained by dividing the total agricultural energies (Table 5) by the total agricultural water. This was obtained by calculating 53 inches of rain per year on the total agricultural land (277.1×10^3 acres, Table 5) plus the irrigation water of 104,000 ac ft/yr.

i. The value was obtained by dividing the total agricultural energies (Table 6) by the total agricultural water. This was obtained by calculating 53 inches of rain per year on the total agricultural land (180.5×10^3 acres, Table 6) plus the irrigation water of 104,000 ac ft/yr.

j. The value was obtained by dividing the total agricultural energies (Table 7) by the total agricultural water. This was obtained by calculating 53 inches of rain per year on the total agricultural land (143.2×10^3 acres, Table 7) plus the irrigation water of 60,000 ac ft/yr.

k. The value was obtained by dividing urban energy (Table 4) by the total municipal water currently used in Brevard County (27.8 MGD).

l. The value was obtained by dividing urban energy (Table 5) by the projected municipal water use of 54 MGD (Table 5).

m. The value was obtained by dividing urban energy (Table 6) by the projected municipal water use of 163 MGD (Table 6).

n. The value was obtained by dividing urban energy (Table 7) by the projected municipal water use of 77.5 MGD (Table 7).

Table 13

Kilocalorie Value of Water as an Amplifier on Total Energy Processed Using Various Kinds of Economic Development (10^6 kcal/ac ft)

	Continued High Rate of Growth	Fossil Fuel Cost Increased by 2	Fuel Rationing and Increase in Cost of Fossil Fuel	Fossil Fuel Held Constant	Light Industrial Growth Increase with Federal Subsidies and Tourism Constant (but no increase in price of fuel)
Primitive [a]	30.7	-	-	-	-
Present [b]	29.9	27.8	27.8	-	-
Private Development [c]	26.4	23.0	21.9	24.1	24.2
Proposed Reservoirs [d]	42.4	31.9	24.5	27.0	35.7
Floodplain Conservation [e]	37.0	32.8	30.8	32.8	34.4

Footnotes to Table 13

a. The values were obtained by dividing the total natural energy (Table 8) in the primitive condition by the total water in Brevard County. (3,698,000 ac ft/yr, Footnote y in Table 3).

b. The values were obtained by dividing the total energy for each of the economic contingencies in the present condition (Table 9) by the total water in Brevard County (3,490,000 ac ft/yr, Footnote y in Table 4).

c. The values were obtained by dividing the total energy for each of the economic contingencies in the private development alternative (Table 9) by the total water in Brevard County (3,410,000 ac ft/yr, Footnote y in Table 5).

d. The values were obtained by dividing the total energy for each of the economic contingencies in the proposed reservoir alternative (Table 9) by the total water in Brevard County (2,927,000 ac ft/yr, Footnote y in Table 6).

e. The values were obtained by dividing the total energy for each of the economic contingencies in the floodplain conservation alternative (Table 9) by the total water in Brevard County (3,552,000 ac ft/yr, Footnote y in Table 7).

Table 14

Energy Value of Water as a Stimulus to Various Types of Natural and Man-made Systems

Ratio of Energy to Total Water with that System in Brevard County	Work Value 10⁶ kcal/acre ft.
Photosynthetic energy on natural[a] land: total water	20.4
Agricultural work:[b] Agricultural water	16.2
Urban energy: total[c] water within city	42.1
Water power	0.018

Table 15

Energy Value of Water as a Stimulus to Various Types of Urban Systems

Ratio of total energy in the city to municipal water used by the city	Work value 10⁶ kcal/acre ft.
Tourist and retiree economy[a] of Naples, Florida: urban water	135
Brevard County economy[b] (partially federally subsidized): municipal water	466

Footnotes to Table 14

a. The value was obtained by dividing the total photosynthetic energy by the total water in Brevard County prior to man (Table 3).

b. The value was obtained by dividing the current agricultural energy (photosynthetic plus fossil fuel additions) by the current water on the agricultural land including rain (Table 4).

c. The value was obtained by dividing the total urban energy (Table 4) by the total water equal to the municipal water (the sum of 9 MGD from Lake Washington, 15-16 MGD from Orange County, and 3.7 MGD from the shallow aquifer near Titusville) plus 53 inches per year of rain on the urban area (Table 4) = 344,708 acre ft/yr.

Footnotes to Table 15

a. The value was obtained by dividing the total urban energy for the tourist based economy of Naples, Florida (Odum, Littlejohn, and Huber, 1972) by the total urban water for Naples.

b. The value was obtained by dividing the current (1970) total urban energy (Table 4) by the total municipal water (31,125 acre ft/yr). Brevard County is currently (1970) a partially, federally subsidized urban area (approximately 35% of the total economy).

SUMMARY AND CONCLUSIONS OF PROPOSED PLANS

In this report calculations were made to show the effect of the Corps of Engineer's proposed reservoir project on energy flow values in Brevard County and to extrapolate some principles to the rest of the upper St. Johns River basin. We used the principle that a region which maximizes its total energy flow (natural energy and fossil fuel energy) will be the one which can compete with other regions and so will survive economically. We evaluated the annual flow of natural and fossil fuel energies of Brevard County under five alternatives. These are: the primitive condition, current (1970) conditions, an extrapolation of current private development, the proposed reservoir plan, and a floodplain conservation plan.

The calculations of the values of future alternatives (private development, proposed reservoir plan and floodplain conservation) differ according to the main external sources of money and energy expected to be available to the region. Fossil fuel costs to power plants have doubled in the last two years, federal payrolls have changed, and tourist trends are uncertain. In this evaluation we considered five possible contingencies of future growth for the county: extrapolation of past growth rates, energy costs doubling, no additional fossil fuel energy possible, cost of fossil fuels double and the amount held constant, and growth of light industry but the agricultural, tourist and federal portion of the economy held constant. Which of these economic contingencies will develop in Brevard County is dependent upon the investment, retirement, and tourist images of Brevard County held by other portions of the nation, by the federal payrolls, and by fossil fuel reserves and policy of the United States and its balance of payment with the rest of the world and other factors. In the evaluation of the five alternatives we were able to answer some of the questions posed in the introduction on the effect of proposed reservoirs on this county.

Questions Posed During This Study

What will be the effect of the reservoir project on the marsh and agricultural land?

a. The land bought or leased by the Flood Control District (FCD) will be the land managed in either reservoirs or marsh under the proposed reservoir plan. In Brevard County this amounts to approximately 47,000 acres with approximately 30,000 acres of this as reservoir area in the valley. Initially the plan has no levees on the sides of the reservoir and if the private owners do not want their land flooded they will have to build levees along the sides. Most of the land is owned by large corporations and large land owners. If dikes are constructed privately and the land continues to be developed for cattle or citrus, the marsh will be decreased from its current acreage of approximately 88,000 acres to 40,000 acres. Most of this marsh will not be on the land owned or managed by FCD. Under the private development alternative the marsh will be reduced to 25,000 acres due to the private diking for agriculture. These figures are derived from current ownership and development patterns. Thus, under the proposed reservoir development plan much of the natural floodplain will be lost and agricultural use of land and water increased.

b. Water quality under the proposed reservoir plan will be poorer than it currently is if the area follows patterns shown in other areas that are adjacent to agricultural canals and stabilized lakes (Brezonik et al., 1969; Wegner and Holcomb, 1972). Phosphate concentrations already have doubled during the year of this study (Bayley and Horsley, 1973).

c. Water levels. Another effect of the proposed reservoirs will be to reduce the water flowing through the floodplain and the surface ground water levels. The water levels have dropped approximately three feet since the 1940's due to diversion to the Indian River and increased channelization which takes water off the floodplain at a faster rate. This will continue under this proposal due to all of the agricultural canals and channels of the proposed project. With diversion of the water from the western slope of the river basin to the agricultural areas to the south (particularly Indian River County) there will be less water entering the river system in Brevard County. Although the water will be retained in a valley reservoir there will be less water to be retained. Any increases in urban demand must be supplied by Lake Washington Reservoir since demands in Orange County will probably not permit additional water to be obtained from that aquifer (currently at 16-17 MGD). The proposed reservoir system is one way but not the only way to provide a water source for urban growth if factors causing this growth continue.

Which alternative of water management is the most valuable to the general overall public interest: The Floodplain Conservation Plan

The most important question posed by this study is which alternative will be the most competitive and the most able to allow the region to survive economically in comparison with other areas under changing conditions. The region which does not use man's money and energy unnecessarily to perform tasks which nature can perform for free will have an economic advantage over another area. Because it retains productivity and water quality, the floodplain conservation plan is calculated as the most competitive system. It keeps the very high natural productivity in the floodplain and adds high urban energy from the coastal areas. Agriculture is restricted to the higher elevations where it will not eliminate the most productive of wetland areas. Water that is now diverted to the Indian River from the St. Johns drainage districts is returned to the river basin under this plan. Rain and irrigation water from the agricultural areas will be returned to the St. Johns river, but through marshes. No canals should be permitted within the floodplain. All agricultural canals end in the higher elevations and the waters drain through the marsh to the river. All urban development should be restricted to higher ground, mainly east of I-95.

The advantages of this plan are many. The region will have both natural and urban productivity but the urban will not destroy the natural areas and the natural area can continue to make a favorable image for the area. The floodplain because it will be restored as a reservoir and flood control aid with more water than currently (there has been approximately 200 cfs loss in flow and 3 foot loss in level since the 1940's). More water will be secured for the larger urban demand while at the same time making a more productive natural marsh. Since there will be no canals in the floodplain the water will be retained longer in the region and the marsh will act in the same manner as a reservoir. It will hold water during the wet season as does a reservoir (and one which has no maintenance costs) and during the dry season gradually release water to the lakes. There is no need for the valley reservoirs or upland impoundments under this plan.

Under this alternative the declining water quality would be improved and marsh act as a living filter for the agricultural wastes that are returned to the system. The lowered nutrient levels would probably reduce the water hyacinths and algal growths which are a major factor in the sediment build-up in the lakes. Thus, sediment accumulation would be stabilized due to decreased hyacinths and increased water flows.

The floodplain conservation plan provides water and land to allow the urban population to double its 1970 levels if the increased population is accompanied by additional money and fossil fuel. Under all of the water management contingencies examined, the floodplain plan maximizes the total energy retaining high natural energy areas but also developing high urban energy values. The floodplain plan has 730 million dollars more value than the proposed reservoirs even with a continued high rate of urban growth. If fossil fuel prices double then the floodplain plan is worth 2.3 billion dollars more to the region than the proposed reservoir plan. The benefits from the floodplain conservation and recycle plan will be derived if the marsh is returned to floodplain as shown in Table 7 and Fig. 15. If the acreages are reduced and the water not returned to the St. Johns River the values calculated will not be valid. There will then be some other type of dry vegetation system with less value.

Comment on the Reservoir Plan and Extent of Urban Growth.

The proposed reservoir system has advantages over the private drainage alternatives, but may not maximize values. Large areas of agricultural land can be irrigated. According to intent, water is to be conserved in the reservoirs for use during dry seasons rather than immediately leaving the area. In an area with alternating floods and droughts the reservoirs are supposed to manage the floods and prevent damage to crops and reduce damages downstream. Until the reservoirs fill with sediment the system is to supply urban water and allow urban development.

Questions as follows suggest the reservoir plan may not achieve these objectives. First, can the plan supply enough water for both agricultural land and urban demands? If 95% of the agricultural demand on 500,000 acres is met (Corps of Engineers, Addendum 1 to Part III, Supplement 2, 1962), and if this is approximately 6 inches per year then 250,000 ac ft/yr are required. Since some (25-30%) is lost in transmission, 325,000 ac ft/yr are required. The agricultural water is to be taken from Jane Green Reservoir and diverted south to the agricultural lands. The westward slope of the valley in the Jane Green Watershed has approximately 340,000 ac ft/yr in water. If agricultural demands will be met first this leaves 15,000 ac ft/yr for urban use. Melbourne currently uses 10,000 ac ft/yr. If urban growth greatly increases, the demand for water will be the greatest during the dry season of drought years. There is little margin for error or contingency. There is little security in this for either farms or towns.

The agricultural demand for irrigation comes mainly from south Brevard County and Indian River County. As shown in Figs. 4 and 5, these are primarily large corporations owning many thousands of acres. Thus, the federal subsidy (for the reservoirs) is going mainly for irrigation water to large land owners. The water currently flows down Jane Green Creek, Wolf Creek, and all the other little creeks into Brevard County. Under the proposed reservoir plan this water will go where the policy of regional agencies directs it. There are valid questions as to the desirability of diverting any county's water resources to promote economic development of another county especially when there are no special amplifier effects or benefits which may be calculated to increase values for the overall region.

Once the water is diverted to the south for irrigation a significant portion of it will never be returned to the St. Johns. Most of the agricultural areas are organized into drainage districts which drain into Indian River. Much of the water will be lost through evapotranspiration or drainage into the Indian River. Water that is diverted back into the St. Johns will have high nutrient levels from the citrus and pasture lands. Nutrients cause increased algae growth in the lakes and increased water hyacinths problems. One of the main problems with water hyacinths is the rapid growth and death of the plant produces large masses which fall to the bottom of the lake and river (or in this case reservoir) and accumulate. Using current sedimentation rates from Lake Helen Blazes, the Lake Washington Reservoir would fill with sediment in 25-35 years. If the nutrient loading is increased, this may be faster since the average depth of the proposed Lake Washington Reservoir is only three feet. Thus additional costs must be added to the maintenance of the reservoir for sediment control.

Quality of Life, Regional Image and Growth Possibilities

A main feature of the reservoir plan is a greater diversion of marshland to other use, causing greater density of attempted development and less buffering green space. If the area does build up a large urban population, what will be the quality of life in the region? Will it be similar to other areas in Florida which have built up dense urban structures? Tax costs increase, congestion increases, and the coastal areas receive large amounts of sewage and sewage treatment expense.

With little green panorama left, the wildlife, fishing, and recreational values in the region decrease. If the region does not get continued cheap fossil fuel, incomes and investment capital, the region will have displaced valuable ecosystems without replacing them with other values.

There are a number of indications that the development trends may not continue in the same manner as in the past. Unless Brevard County can obtain additional large federal payrolls that portion of the economy will remain constant or decline. Fossil fuel costs have been and are expected to continue rising. New capital investments in Florida are based partly on the undeveloped lands which will be converted into urban dwellings and agricultural lands. As more of the land is developed, this may then decline. Much of the ability of the county to attract inhabitants and capital is dependent upon its image in relation to other areas. Part of this image is made up of the quality of life indices, the coastal beaches and natural inland areas such as the marshes, river, and lakes of the upper St. Johns. Population levels in the rest of the U. S. and the balance of payments and the national economy have a large influence on the continued rate of development within Brevard County. If the federal payrolls remain constant and the tourist and retirement inflows stabilize due to changes in savings and inflation, growth would depend on light industrial development but the ability of the county to attract such investments may be dependent in part on the image. With the drainage of the marshes and loss of inland panorama, increasing pollution of the coastal areas, and higher urban densities with its associated higher taxes and costs, the region may find it more difficult to compete with other areas for more limited industries and investments during times of poor balance of payments.

If the region does not continue to get some source of new income and energy, the prior drainage of large acreages of natural land and installation of the reservoirs will put the county in a poorer total condition than it is today ($9.4 billion vs. $10.5 billion). This is due to the loss of large productive natural regions without replacing them with another large productive system - urban and fossil fuel energies.

As urban development proceeds more dollars and energy are brought in but more services and tax dollars are required. As long as the outside subsidy of energy and capital continues to come to the region the high tax costs of these services are only a part of the total monetary economy, but as the region gets denser these tax costs become a larger and larger portion of the total economy encompassing such regulatory costs as special sewage plants, solid wastes works, special recreation costs, police forces, education services, and urban bureaucracy. With any loss in the outside subsidy, the county is in a precarious position with a dense urban structure to maintain and declining funds to maintain it.

As energy use goes up an increasing portion of the work is spent in self maintenance. And these urban energies overwhelm the natural environment in proportion to their energies. So if the urban region is growing rapidly, the natural environment and its role in promoting growth is being stressed. The computer simulations in Fig. 19 and 20 and summarized in Table 20 show the urban stress on the natural regions in this realistic manner. In these simulations the total value of Brevard County declines with the proposed reservoir plan and with continued private development in the floodplain. Attempts to promote growth beyond the density for maximum value puts a stop to growth.

Consequences of Continued Private Development in the Floodplain without Either the Reservoir Plan or a Floodplain Conservation Plan

The consequences of the private development alternative without either the reservoir plan or a floodplain conservation plan is a loss in value. The drainage and channelization has proceeded and is continuing in the floodplain so that the water levels have dropped an average of 3 feet in Lake Washington (the source of municipal water). Continued channelization will take the water out of the region even faster and the county will not be able to use the St. Johns River for additional urban development. In drought years the region may not be able to supply the current demand. A more reliable water supply regime is required for attracting additional incomes and investment capital.

The drainage of the water by agricultural interests is in direct competition with the needs of the urban community for an urban water supply. Since the agriculturalists own much of the floodplain under current practices they control public water policy by their land practice.

In addition to reducing the quantity of water under this plan the water quality will be poor. Current data shows the agricultural canals have 5 to 8 times more phosphate than the adjacent river and much higher salinities. Poor water quality gives rise to algal blooms (and the attendant increased water treatment costs) and water hyacinths. These will have the same effect under this alternative as in the reservoir plan which is to increase the sediment accumulation. In this plan a reduction in the volume of the lake will leave less area for water storage and water will leave even faster.

With this plan, the natural productive areas are greatly reduced and replaced by agriculture. The urban development is curtailed by shortages in the available water which has been drained to make agricultural land. Yet agricultural values are lower than both natural and urban energies and give this a very low overall value. Agricultural sales in Brevard County currently (1970) make up about 1% of the total economic budget of the county. In Indian River County this is about 16%. This is a small portion of the total economic budget yet the consequences in terms of land use and energy flow are much greater.

Extrapolation of Conclusions Beyond Brevard County

In a region which is seasonally short of water, one way to help decide between water management plans is to look for the system that gives the most energy per unit of water available. In Brevard County the greatest energy per unit of water was obtained by the proposed reservoir plan only if incomes increased and fossil fuel price did not increase. With increasing costs in fossil fuel, the floodplain recycle plan provided the greatest energy per unit of water. If the other counties in the St. Johns basin are similar to Brevard County in land use and productivity per unit of land, then one may expect to maximize values in the larger region using the same land proportions and water uses. A plan which retains some marshes and provides a mixture of land uses may maximize value in the entire upper St. Johns River basin. With increasing costs in fuel and uncertain incomes the best plan may be one which conserves the naturally productive areas and designates agricultural and urban uses of land to those areas which are less productive.

Safety in Diversity: A Principle in Planning

In a region where large scale changes are being planned, it is risky to assume that future development and income can be extrapolated from past trends based on one or two growth activities. One principle available for planning in a time of changing fossil fuel costs and uncertain monetary trends is the diversity concept. Providing for a diversity of land use may give flexibility and stability to the region allowing the system with the highest value to develop. It is safer not to put all of the planning into one concept, dependent upon many factors that are uncertain. The floodplain plan develops a more diverse land use pattern by putting part of the region into urban development and leaving part of the region in highly productive natural areas that do not require subsidy from man in the event that fossil fuels and money become limited in Florida.

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